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RTMAP
BMR REGOLITH DATABASE FIELD HANDBOOK

Prepared by

Colin Pain, Roslyn Chan, Michael Craig,
Murray Hazell, Julienne Kamprad, and John Wilford
(BMR Regolith Group)

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Other regolith publications:

1. Ollier, C.D. 1984b— Glossary of Morphotectonics, BMR Record 1984/24.

2. Chan, R.A., Craig, M.A., D'Addario, G.W., Gibson, D.L., Ollier, C.D. and Taylor, G., 1986— The Regolith Terrain Map of Australia 1:5 000 000, BMR Record 1986/27.

3. Ollier, C.D. and Joyce E.B., 1986— Regolith Terrain Units of the Hamilton 1:1 000 000 Sheet Area, Western Victoria, BMR Record 1986/33.

4. Chan, R.A., Ollier, C.D. and Gibson, D.L., 1988— Regolith Terrain Data, Kalgoorlie 1:1 000 000 Sheet SH–51, Western Australia, BMR Record 1988/3.

For further information, contact:

Regolith Group, Minerals and Land Use Program
Bureau of Mineral Resources
GPO Box 378
Canberra ACT 2601
Australia
Phone (06) 249 9469 or (06) 249 9371
Fax (06) 257 6465

PREFACE

In line with its objective of providing better data about the Australian regolith to interested persons and organisations, the Regolith Group at BMR has developed a database to contain information about the Australian regolith. This database (RTMAP) uses the ORACLE database management system, and records attributes of both regolith and terrain for areas mapped by BMR. We are also hoping to obtain data from other people and organisations working on the Australian regolith.

We have also begun the development of a spatial database using a Geographic Information System (ARC/INFO), and will link the ORACLE database to the GIS. RTMAP has been designed with spatial data attributes in mind.

The details of the structure of RTMAP are set out by Lenz (BMR Record 1991/30). That Record is intended for use by people entering data into RTMAP, and also for people interested in the details of the database design. It describes the structure of the database and how to make amendments to it should they be necessary. It also describes how to insert, update or delete records from the database, and how to retrieve data in the form of basic reports.

In this record we are providing information for people mapping Regolith Terrain Units in the field and from maps. First, we introduce the regolith and some ideas about what it is and how to map it. Second, we include a set of lists for those fields in RTMAP where the choice of entries is limited. These lists are of two types, and contain the allowable choices for entry into fields in particular tables. There are the authority tables, which are separate tables in RTMAP. There are also shorter lists which do not warrant creation of their own tables. Third, we provide definitions for most of the entries in the lists.

Ollier (1984b) has already prepared a *Glossary of Morphotectonics,* in which a number of terms relevant to regolith are defined. Readers should also refer to that publication.

The Regolith Group is currently mapping regolith at a scale of 1:250 000 in the Yilgarn, in North Queensland, and in the Forbes–Bathurst area. Regolith Terrain Unit data will be available in the following forms:

1. Hardcopy "preliminary" maps produced on either a pen plotter or electrostatic plotter. Each map or set of maps will be accompanied by a database report.
2. Hardcopy "first edition" maps produced by the BMR Cartographic Services Unit from digital files. These maps will be accompanied by a set of notes and, if required, a printed report from the digital database.
3. Digital GIS files (formats on application). These digital map products will consist of two layers, a polygon layer of regolith terrain units, and a layer of morphotectonic and geomorphic features. A full digital database will also be available on request.
4. We are also looking into the possibility of producing special "user-defined" maps and reports from the GIS.

Prices have yet to be determined.

We will be upgrading this manual from time to time as our work progresses, and as we receive feedback from users of our products. We are developing a list of users of BMR regolith data in order to send them information about updates to this manual, and about new regolith data releases in general. If you wish to be on this list, please let us know.

Colin Pain
Manager, BMR Regolith Group

CONTENTS

1 REGOLITH AND REGOLITH MAPPING

This chapter introduces regolith concepts and mapping techniques, and forms a theoretical basis for later chapters which introduce the database, list the terms used, and provide definitions.

1.1 WHAT IS REGOLITH?

There are a number of definitions of regolith to be found in various journals and books. The word itself was introduced by Merrill (1897) and has been in use since then. The term comes from the Greek *rhegos* = blanket and *lithos* = stone. In other words, the blanket over the rock.

The following definitions give the general idea of what we mean by the term *regolith.*

> A general term for the layer or mantle of fragmented and unconsolidated rock material, whether residual or transported, that nearly everywhere forms the surface of the land and overlies or covers bedrock (Chan *et al.* 1986).
>
> The mantle of materials, including weathered rocks and sediments, altered or formed by land surface processes (Speight and Isbell 1990).

Regolith includes rock debris of all kinds, including weathered rock in place, alluvium, colluvium, aeolian deposits, volcanic ash, and glacial till. It is commonly called "soil" by engineers, but for our purposes, soil is organically influenced regolith which is at the surface. These points have been emphasised in earlier work by the BMR Regolith Group (Ollier and Joyce 1986, Chan 1988, Chan *et al.* 1988).

The underlying zone of rocks formed or altered by deep–seated crustal processes is the bedrock. Regolith and bedrock are thus characterised by different processes, rather than different materials. Regolith is bedrock which has been altered by processes at or near the surface including weathering, erosion, transportation, and terrestrial sedimentation. This includes induration of regolith by cementation to form, for example, duricrusts. Thus some regolith is not unconsolidated, but is very hard. We need a pragmatic approach to the problem.

1.2 REGOLITH RESEARCH

The study of regolith can be approached in a number of ways. These include detailed mineralogical and geochemical studies, mapping of small areas, and regional mapping. There is a need to answer such questions as: Is the regolith at a site transported or *in situ*?, What is the nature of weathering? and; What does the regolith tell us about the suitability of land for a variety of uses? Good information about the regolith can also assist with the interpretation of (see Chan 1989):

* geological maps
* soil geochemical surveys
* stream sediment geochemical surveys
* airborne geophysical surveys
* shallow drilling

How do we get the information? There seem to be two general approaches. One is to map the regolith, and try to work out the stratigraphic details of regolith materials. The second is to study the mineralogy and geochemistry of the regolith in an attempt to explain its origins and associations.

Mapping the regolith requires considerable field work. Moreover, much of this mapping must rely on observations of headwalls, road cuttings, stream banks and other exposures. These exposures give us information that drill cores can never give us. It is often impossible to identify regolith materials from drill holes. A core or hand specimen of sand or clay gives little clue to its origin. We need to know about the three dimensional characteristics of the regolith to make a positive identification of both its type and genesis. This is not so true of hard rocks, where identifications can often be made on the basis of drill cores or even chips of rock.

We are thus seeking information not only about the regolith, but also about the landscape relationships of the regolith. We are not simply revising the stratigraphy of the upper part of the stratigraphic column. We are documenting the regolith and its landscape relationships in a way which will allow prediction of results from one area to another.

A considerable amount of research has been carried out on the mineralogy and particularly the geochemistry of regolith in Australia (eg Bird and Chivas 1989, Butt 1987). This research is concerned with weathering changes in the regolith, and the pathways of elements through the regolith. Much of it has concentrated on the regolith of small areas, and there is little published on the relationships between geochemistry and landscape position (see, however, Butt and Zeegers 1989).

Mapping on the one hand, and geochemical and mineralogical studies on the other hand, are thus rather different in the kinds of information they produce, and there is a great need to integrate them to give a fuller picture of regolith cover. The BMR Regolith Group is, for the moment, concentrating on the regional mapping approach, in line with National Geoscience Mapping Accord priorities. We hope to undertake work to combine the mapping with the detailed study of regolith characteristics in collaboration with other agencies.

1.3 MAPPING REGOLITH

1.3.1 General Approach

In designing an approach to mapping regolith we must keep in mind the purpose of the mapping program, and the users of our map products. The Regolith Project was initially set up to answer questions raised by the mining industry, but recent trends suggest that we shall be answering landuse questions as well.

These two purposes are rather different. At the regional level of our activities, the mining industry would like to know about the genesis and history of various regolith types, correlations between various regolith units across the landscape, and the associations between regolith and the underlying bedrock. They would also like to know the relationships between regolith type and mineral deposits, and the distribution of various regolith types with economic potential. Moreover, regolith types and their landform associations may give clues to bedrock mineralisation (Chan 1989).

People with interests in landuse, on the other hand, will be concerned not only with those things that interest the mining industry, but also with those aspects of the regolith that have a bearing on land suitability for various uses, as well as degradation and environmental fragility.

1.3.2 Regolith Terrain Units

Regolith is not easily mapped. Even soils, the upper "skin" of the regolith, generate much argument about their mapping, and soil maps do not indicate the characteristics of the regolith at depth. It is possible to look at the regolith at any point in the landscape, but there is a practical limit to doing this. The only land features that can be mapped with speed and accuracy are surface features, or terrain. We must therefore establish the relationships between regolith and terrain. Moreover, this must be done for each locality, because the systematic study of the regolith is in its infancy, and there are as yet no universal laws that relate regolith to terrain.

Regolith contrasts with hard rock bodies in several important ways which influence the way we can study it.

* Regolith types are generally much thinner than hard rock units. They occur as a thin, sometimes discontinuous, layers over the hard rock. Hard rock mapping techniques are therefore inappropriate for mapping regolith.

* Individual units of sedimentary regolith are usually discontinuous. They may occur as accumulations of sediment in the

lower parts of the landscape (eg fluvial sediments in valley floors). Because of this discontinuity it is generally inappropriate to give formal rock unit names to bodies of terrestrial sediments. With few exceptions there is no reason to suppose that these bodies can be correlated from one drainage basin to the next, let alone across much wider regions.

* Weathered regolith occurs as "skins" of various kinds, differing with age of landsurface, and underlying rock. Despite attempts to show that particular weathering patterns, such as duricrusts, can be used to correlate different land surfaces, it is becoming clear that this cannot be done with any degree of confidence (eg Ollier and Galloway 1990,). Duricrusts are an obvious part of the regolith, and of the landscape, but they have been over–represented in much of the work carried out on landscapes in Australia. In a sense they are "red herrings", because their influence can often be shown to be only minor.

* Similarly, it seems unrealistic to speak of "periods of weathering" in anything but a very broad sense. Weathering continues from the moment a land surface is exposed until it is destroyed either by erosion or buriàl. Deep weathering is primarily a product of a long period of stability in a landscape.

* At a local scale, in a particular landform type for example, there is commonly a strong relationship between the present landform and regolith cover. This expresses itself in the phenomenon known to soil scientists as a toposequence. Toposequences are systematic variations in soil morphology with position in a landscape. This concept fits regolith very well, and can be used in a predictive sense once the toposequence relationships are worked out.

What surface terrain feature or features do we use to map regolith? Regolith is an integrated expression of geology, climate, landforms, geomorphic processes and landscape evolution. It will be clear from the very close relationship between regolith and landforms that landforms are the most important of these factors. This is because they are expressed on the surface, and they reflect many of the other attributes listed above. Moreover, the formation of regolith types is closely associated with the formation of landforms. This means that, as a first approximation, we may use landforms as a surrogate for regolith (Chan 1988). In this respect, our mapping methodology has its origins in techniques developed for mapping terrain and soil (Stewart and Perry 1953, Ollier 1977). However, we are concerned with the characteristics and distribution of the regolith rather than the terrain *per se*.

The BMR thus maps Regolith Terrain Units (RTUs). Chan (1988) notes that a Regolith Terrain Unit

> "consists of one, or more usually, several recurring landscape elements and their associated underlying regolith packages which together form a distinct regolith terrain entity."

A more general definition is:

> A land area characterised by similar landform and regolith attributes; it refers to an area of land of any size that can be isolated at the scale of mapping.

Note that these definitions make the RTUs independent of scale.

A survey of Regolith Terrain Units delineates the RTU pattern of an area and characterises each kind of RTU in a way that can be used as a basis for prediction. This prediction can take the form of identifying similar regolith terrain types elsewhere in the study area, or more specifically the prediction of mineral prospectivity (Chan 1989). The survey is carried out in a way that provides base information of general application. This eliminates the need for a resurvey whenever a new problem arises. The survey supplies information that can be combined, analysed, or amplified for many practical purposes, but the purpose should not be allowed to modify the method of the regional regolith survey in any fundamental way.

In the context of mapping within the Bureau of Mineral Resources it is worth pointing out that the techniques of Regolith Terrain Unit mapping are different from those employed for mapping of rock stratigraphic units. RTUs are units of land, using the term in its broadest sense. The methods used to map them have more similarities to mapping of soils and land systems than stratigraphic units.

At a more detailed level, it may be possible to map units that are essentially composed of similar regolith materials, and the methods used for this more detailed mapping would be similar to those used for stratigraphic units. Nevertheless, even at this level of detail, it is inappropriate to give units of regolith material formal stratigraphic names. We are not simply formalising the "yellow" areas on traditional geology maps with more detailed stratigraphic work. In general, regolith is not amenable to this kind of procedure, for the reasons already given above.

Thus, at the level of RTUs, we are for all practical purposes mapping land units rather than units of material. In what follows, we consider the problems associated with mapping RTUs.

The fundamental basis for mapping RTUs is landforms. Reconnaissance surveys of soils, land systems, and RTUs will in all likelihood produce very similar boundaries. This is because landforms are used as a surrogate for the attributes we are really attempting to map. Landforms are usually related genetically to soils and to regolith in a way which is not true for hard rock stratigraphic units. Landforms and regolith are formed by essentially the same group of processes, and once we understand the interrelationships between regolith and landforms, we can use landforms to predict regolith patterns. This means not only understanding the dynamics of the present landscape, but also determining its genesis, and the genesis of the various relict landforms and regolith materials that are found in the present landscape.

Initial boundaries are drawn on the basis of landforms, and the resulting map polygons are described in terms of regolith types and landforms. In many cases these will be the final boundaries. However, if it is warranted, subdivision of these landform–based units into RTUs can be carried out on the basis of regolith type, or associations of regolith type in either areal or vertical extent. For each RTU we record a wide range of attributes. These attributes are listed in the chapter on the database tables.

The Regolith Terrain Unit classification is used as a basis for presenting regolith information on maps. It is loosely hierarchic, and open, and identification of units proceeds from the highest levels of landform and regolith type through a number of open choices to lower levels (Table 1.1). In practice the level reached in the hierarchy of landform and regolith classifications depends on the scale of mapping.

Table 1.1 Criteria for Regolith Terrain Map Legend

	Level 1	Level 2	Level 3
Deep Weathering Dominated (> 2m thick)	regolith type	landform type	open
Bedrock Dominated (regolith ≤ 2m thick)	regolith type	landform type	open
Sediment Dominated	regolith type	landform type	open

Note: Further subdivision is possible using any appropriate criteria.

In producing regolith terrain maps, a major distinction is made between bedrock dominated terrains, deep weathering dominated terrains and sediment dominated terrains. These three basic subdivisions are largely a result of landform evolution, and reflect the relationships between weathering and erosion.

1.3.3 Classification versus Mapping Units

The arrangement of regolith terrain units in a classification is based on logical and hierarchical relationships between the different kinds of regolith terrain. However, such an arrangement has little in common with the spatial arrangement of these units in a landscape. The arrangement of regolith terrain units in a landscape depends on the geomorphic development and character of the area. There is thus a fundamental difference between regolith terrain classification units and regolith terrain mapping units.

Classification units consist of regolith terrain units which are defined in terms of various regolith/terrain characteristics. They are ideal or conceptual units which can be precisely defined. They are used as a medium for the transfer of knowledge, and can be grouped in various ways for particular purposes. In traditional geology the equivalent is lithologic units, for example, granite and sandstone.

Mapping units are real regolith terrain units that can be conveniently mapped, and their definition will therefore depend to some extent on the scale of the map. The more detailed the map scale, the more pure the regolith terrain mapping units will be. A mapping unit will almost always include regolith terrain units that do not belong to the appropriate classification unit. These different units occur in areas that are too small to appear on the map, for example, narrow sedimentary areas in floodplains in dominantly deeply weathered terrain. An equivalent in traditional geology is the various named rock units that are shown on a standard geology map.

1.3.4 Mapping Scale

So far the BMR has produced three RTU maps. These are the 1:5 000 000 map of Australia (Chan *et al.* 1986), the Hamilton 1:1 000 000 sheet (Ollier and Joyce 1986), and the Kalgoorlie 1:1 000 000 sheet (Chan *et al.* 1988). These maps were produced in the belief that a broad overview was preferable to more detailed mapping. The overview was necessary to place detailed studies in context. The regolith work aimed to follow the classic survey principle of working from the whole to the part. The plan was thus to produce a series of 1:1 000 000 quadrangle RTU maps of Australia – about 40 in all.

With priorities now being influenced by the National Geoscience Mapping Accord (NGMA), we will carry out regional mapping, at 1:250 000, compiling from 1:100 000 field maps. We will generalise from the 1:250 000 maps to the 1:1 000 000 scale to complete sheets at this broad scale.

2 MAPPING PROCEDURES

In this chapter we set out some of the details of producing regolith terrain maps. Most of the material set out here is well known to workers concerned with land surveys but may be of value to more traditional geologists. Other aspects of survey procedure are included to make the details of our methodology as complete as possible.

An understanding of landform mapping is very important for regolith terrain mapping. This is true for the following reasons:

1. Regolith terrain units are based on landforms, so it is important to be able to recognise different landform types.
2. Landforms tell us something about the underlying rock types. At its simplest, for example, low gently sloping landforms are often found on softer rocks, while steep mountains are often found on harder rocks.

An important aspect of mapping landforms and regolith terrain units is that the study of small sample areas that are representative of larger areas allows us to transfer our knowledge from the sample areas to the larger areas. This is extrapolation and is an important part of regolith terrain unit surveying. It is also important to understand that extrapolation from landforms to regolith terrain units requires valid conceptual models of landform and regolith evolution. The equivalent in bedrock geology is subsurface extrapolation from outcrops.

There are several ways we can get information about landforms. Landform types can be recognised on maps, especially topographic maps. Contour lines and spot heights give us landform information, especially elevations, relief and dissection, and drainage patterns. Geology maps help explain landform distributions by giving the distribution of different kinds of rocks. Soil maps may also be useful, particularly where the soil type descriptions include information about their parent materials.

Landforms are easily recognised from remotely sensed images such as aerial photographs, Landsat and SPOT images and airborne and spaceborne radar images.

Field interpretation of landscapes is also important. Fieldwork is carried out to confirm and characterise the relationships between regolith and landforms.

2.1 BEFORE FIELD WORK

Collect as much information as possible about the survey area before field work. This should include a literature survey to find out what has been done in the area before the current survey, and a study of the available maps and images of the area. Here we consider only maps and images, although any drill hole, geochemical and geophysical data available should also be examined.

2.1.1 Information From Maps

Two major kinds of information can be obtained from maps. Geological and soil maps provide you with information about subsurface materials, while topographic maps give you information about landform shape, pattern and elevations.

2.1.1.1 Geology Maps

Most commonly the legend of a bedrock geology map is presented on the basis of the age of the rocks. The rocks in the map area are classified according to the geological period in which they were formed. Unfortunately, this is often not much use to someone interested in landform, or regolith terrain mapping. It is therefore necessary to interpret the legend in a way which is meaningful for regolith terrain units. There are two aspects to this, the recognition of lithologic types, and the grouping of geology map units to give a map of lithologic types.

2.1.1.2 Soil Maps

Soil maps vary a great deal in the amount of useful information they contain about the regolith. Most soil maps, irrespective of the classification system used, contain information about the parent materials of the various soil units mapped. On more detailed maps, the soil mapping units may be grouped to reflect the parent materials. However, at a reconnaissance scale, soil maps are usually prepared using landforms as a surrogate for soils, so the information they contain about the regolith is less specific and thus less useful. However, the boundaries on such maps will often be very similar to those of RTUs. The major difference between a soil map and a regolith terrain map is that the latter describes the regolith, of which the soil is only the uppermost layer.

2.1.1.3 Topographic Maps

Topographic maps contain a great deal of information about the nature and distribution of landforms. Contours and spot heights give elevation information. Spot heights give simple elevations for points. Contours, on the other hand, give more information than just that relating to elevation. They give information about land slope, and it is therefore possible to prepare a map of landforms from a suitable topographic map. The accuracy of the map will depend on the contour interval. Contours also give information about the degree and depth of dissection. Moreover, it is possible to obtain real values for these features. The contour values give the depth of dissection, while measurements or estimates of relative areas of interfluves and incised valleys give the degree of dissection. The following definitions will help with this:

> *Depth of dissection* is a measure of the depth to which rivers have cut down below some general level. It is assumed that the rivers began cutting down from the same general level.
>
> *Degree of dissection* is an indication of the amount of the original surface that is left. A slightly dissected surface has only a few valleys cut into it, while a highly dissected surface may have only a small part of the original surface left.

In areas where there is nothing left of the original surface, it is unrealistic to use the term *degree of dissection*. These areas are completely dissected, and should be described in terms of their relative relief and drainage density. Relative relief is another important feature that can be obtained from contours, and is a measure of the average difference in elevation between the highest and lowest parts of the area under study. It is a relative measure, and is not related to absolute altitude (elevation), which is height above sea level.

Most topographic maps show the rivers and streams of the area covered by the map. If you have a spare copy of the map, it is useful to go over all the rivers and streams with a dark pencil so that the drainage lines and patterns stand out against the rest of the map. In this way, particular drainage patterns and densities will be clearly visible.

The following definitions should be remembered when using drainage lines on maps to obtain information about landforms:

Drainage density is a measure of the amount of drainage lines in an area, and is usually calculated as length of drainage channel per unit area (e.g. km/km^2). It is an indication of the amount of surface water flowing in channels in the study area. All channels which carry water, whether permanent or intermittent, are counted.

Channel spacing is another way of measuring the amount of drainage. This is obtained by drawing a straight line of a given length across a mapping unit, and counting the number of channels the line crosses. Speight (1990) discusses this measure, and gives a formula for converting channel spacing to drainage density. Channel spacing is used in RTMAP.

Drainage patterns are the plan shapes made by the drainage lines. Examples of drainage patterns are dendritic and rectangular.

Channel patterns are the plan shapes of individual channels. Examples of channel patterns are meandering and braided.

2.1.2 Regolith Information from Images

Traditionally aerial photographs have played an essential role in mapping of most land attributes, including geology. Photo scales of 1:10 000 to more than 1:100 000 have been used successfully for many years in landform mapping. The advent of images acquired from satellite platforms since the early 1970s has provided us with a new data source, with images covering much wider areas than aerial photographs. There is tremendous scope for using images, especially digital images, to obtain information about regolith and landforms. However, the subject is too complex to consider in any detail here. Instead we provide some guidelines, concentrating mainly on the delineation of RTUs.

2.1.2.1 Image Types Used for Landform Mapping

In this section we will consider very briefly the different types of images used for landform mapping, particularly from the point of view of the different information they contain. Aerial photographs are the traditional tool for landform mapping. Boundaries between landform types are easily drawn on the photographs under a stereoscope, and then transferred to a map.

Satellite scanners such as Landsat (MSS and TM) and SPOT are well known sources of images for landform mapping. An important difference lies in the range of electromagnetic radiation which is captured by the scanner sensors. With aerial photographs, the images are usually restricted to the range of visible light, although infrared photographs also cover the near infrared. Scanners, on the other hand, may receive radiation from a wide range of wavelengths. These wavelengths are sensed in narrow wavelengths bands. In particular, some information is received in narrow wavelength bands in the near infrared. These bands are less affected by atmospheric interference, and so tend to contain more landform information than the visible wavelengths.

Initially these images were not stereoscopic. However, we now have stereoscopic imagery from SPOT covering large areas at a suitable scale and resolution to be useful for mapping landforms at scales ranging upwards from 1:50 000.

Other image types that are of value to regolith mapping are digital terrain models (DTMs), and radiometric images. DTM images are derived from elevation data and so give direct information about landforms, including shaded images that are a 3D representation of the landforms. Radiometric images, on the other hand, give surface chemical data which can be used directly for mapping surface regolith. We are actively carrying out research on the use of these image types, and will include results in updates of this handbook.

2.1.2.2 Image Features that Contain Landform Information

When mapping landforms from imagery of any kind, it is important to know which characteristics of the images we are using to obtain information about landforms. The standard image characteristics for interpretation are tone (colour on colour images), lines, texture, and shape. Of these, colour or grey tone result from ground cover rather than landforms and are therefore of less interest to us than the other three characteristics. However, we should note that in areas where there is little or no vegetation and the regolith is directly sensed, colour (i.e. pixel values) may be of use.

For landform mapping we can therefore choose wavelength bands which are least affected by atmospheric interference, because we are not looking for specific colours or grey tones. In practice this means use of near infrared bands such as Landsat MSS band 7, Landsat TM bands 5 and 7, and SPOT band 3. Normally one band is enough, because we are not usually interested in colour composite images, which tell us more about ground cover than landforms. However, we make use of multi–band data, and process it to highlight landform features. For example, the first principal component of a number of bands often contains a great deal of landform information.

Whatever the type of image we have to work with, there are routine procedures to be followed for landform mapping, in particular the use of the image features discussed in the next three sub–sections (Pain 1985).

Lines:

Three kinds of lines observable on images are used in landform mapping. These are structural lineaments, ridges and rivers. Structural lineaments are easily seen on most images, especially Landsat and SPOT, and are a useful way of telling the difference between landforms with strong structural control and those that have no structural control. It is necessary to take care, however, because not all straight lines on images result from rock structure.

Because structural lineaments are almost always revealed in the landscape by erosional processes, it is reasonable to place areas with obvious lineaments in the major category of erosional landforms.

Ridges and rivers, or valley floors, can be considered together, because together they make up most of the landscape. We can recognise four major categories on images:

Distinct ridges and rivers
Rivers without ridges
Ridges without rivers
Neither ridges nor rivers.

These major categories can be illustrated as profile forms (Figure 2.1).

Where stereoscopic imagery is available, there is no problem distinguishing many more different profile types. Where there is no stereoscopic imagery, recognition of the four types noted above can be very useful. However, it can often be difficult telling the difference between flat and gently rounded terrain on such imagery, and also seeing small drainage channels that are less than the ground resolution of the available imagery. Under these circumstances discriminating ridges and valley bottoms on images may be very difficult. Moreover, because of the lack of elevation data, it may not be possible to distinguish between low plains and

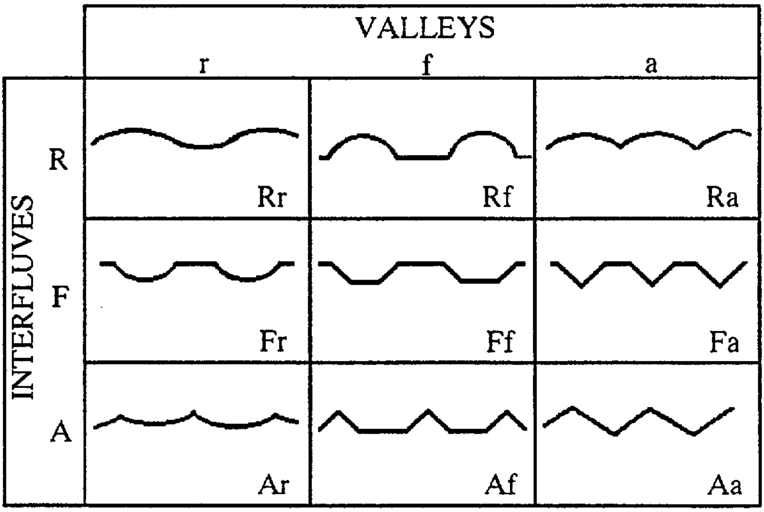


Figure 2.1. Possible combinations of valley and interfluve profile shapes (Ollier 1967). These shapes can be recognised in large part on images.

high plateau. For this reason it is important to use images in conjunction with maps.

Texture:

Texture can be used to distinguish between areas that have different densities of dissection (drainage densities), or repetitive landform features. A simple classification might be smooth, fine and coarse texture, but often imagery will allow more classes. Areas with smooth textures usually indicate low relief and very little change. Coarse textures indicate low drainage densities, and fine textures may indicate high drainage density.

Shape:

Shape is important mainly because of the direct evidence it gives for particular landform types. Shape provides information that can be used with other features in classifying land units. For example, volcanoes usually have a distinct shape, as do beach ridges.

2.1.2.3 Recognition of Land Units on Images

The only way to learn how to recognise landform units, or any other sort of units, on images, is by practice. However, there are a few simple rules that can be followed.

1. Keep in mind the features listed above when viewing the images.
2. Remember that you are looking for landform features. Features on many images are dominated by vegetation or land cover. Do not let these features confuse you in your interpretation of landform units.
3. As you draw boundaries, make notes about the characteristics of the areas inside the boundaries. In this way you can see why you are drawing boundaries. Always complete your boundaries. Do not leave lines hanging.

2.1.3 Regolith Information

There are abundant drill hole, geochemical and seismic data available for many parts of Australia. Find out what is available for your project area, and see how it fits in with the preliminary boundaries you have drawn.

2.1.4 Preparation of the Pre–field Map

The landform unit boundaries derived from the images should be compiled onto a map. For a 1:250 000 scale final map, the pre–field maps should be at 1:100 000. This is a convenient scale for mapping in the field, and topographic maps are readily available at this scale for much of Australia.

At least 2 copies of each 1:100 000 map sheet should be available. One should be kept flat and clean in the home office, for digitising any base data required, and for reference. The second can be taken in the field, and used as necessary. RTU boundaries can be transferred onto this field map before going into the field. A copy of the

RTU boundaries should also be made on stable film. This copy can be amended as necessary in the light of field results.

Preliminary RTMAP data sheets should also be completed for each mapped RTU on the pre–field map.

2.2 FIELD WORK

Fieldwork is an essential step in mapping regolith terrain units. This is when you confirm or change the impressions gained from the images and maps, and see for yourself what the landscape and regolith really looks like. It is also important to check the relationships between the landform characteristics of the different regolith terrain units, and the geology, regolith and soils that cannot be directly observed on the images.

In addition to completing field–site forms, always make notes about everything of relevance to the mapping exercise. This is important. When you are in the field you will already have done your image and map interpretation, and you will also be able to see the landscape in front of you. You have all the information you are ever going to have about the area with you! Make full and complete notes, on the assumption that you will never return to the area for further checking.

2.2.1 Reconnaissance Checking

The first step in fieldwork should be a reconnaissance of the area of study. This can be made by driving through a representative part of the study area, or that part of the study area near your base. It is good practice to get to the higher points in the landscape so you can see more than one RTU. If possible, a survey flight over the project area is also valuable. This overview gives a good idea of the general features of the landscape, and also allows you to place the different RTUs in context. The reconnaissance should also be used to check the general relationships between RTUs and geology.

2.2.2 Selection of Sites

Wherever possible, sites should be selected on or near roads and paths. This will make fieldwork efficient, and less time consuming, while still allowing good field observations. Before going into the field, note the location of the different land units in relation to transport routes, and make your field plans accordingly. Remember that one of the essential reasons for mapping land units in the first place is to allow extrapolation from known areas to unknown areas. In most cases it is possible to extrapolate your observations from accessible areas into areas that are far from roads or paths.

Wherever possible, use road cuttings, river banks, or other exposures for your observations of rock types and regolith.

2.2.3 Landscape Observations

Observations of the landscape (in its broadest sense) can give a lot of detail that is not available from maps and images. For regolith terrain mapping, remember that the map has at least two uses, mineral exploration and land assessment. For the first use you should be looking for any relationships between landforms, regolith, and mineral deposits. For the second, a thorough inventory of land resources is needed (see Dent and Young, 1981, for details on land resources inventory and mapping). In both cases it is essential to look for explanations of the landscape – its origins, active and relict geomorphic and weathering processes, and any information that will allow extrapolation to areas you will not be able to visit.

2.2.3.1 Landform Characteristics

Images and maps give a general idea of landform characteristics, but field observations give the opportunity to get information about the details of landforms. Note whether the slopes are smooth, undulating or irregular, and whether there is any obvious control by underlying rocks.

2.2.3.2 Geomorphic Processes

Make a note of the types of geomorphic processes within RTU boundaries. Landslides can easily be recognised. Surface wash and other types of geomorphic processes can also be recognised with practice. Note both active processes, and evidence for prior processes that led to the formation of the RTUs as they are at present.

2.2.3.3 Dissection

As we have seen, dissection can easily be observed on images of suitable scales. However, it is important to supplement the information obtained from images with field observations. Depending on the scale of the images, you may have missed the detail of dissection of individual slopes. This can include gullies that are cut into slope materials. The nature of the dissection can also be noted in the field in a way that is not possible with images.

2.2.3.4 Rock Types

During the reconnaissance trip you will have noted something of the lithologies, and how they relate to regolith terrain units, and to the mapping units on the geology map. At the detailed site observations, note the lithologies not only at the site itself, but also in the surrounding area. It is often useful to find contacts between different rock types. This will allow you to compare rocks on both sides of the contact, and also to note any changes in regolith and landforms that may occur from one side of the contact to the other.

2.2.3.5 Surficial Regolith and Soils

In common with other observations you make about the RTUs, do not confine yourself to the specific sites chosen for detailed description and sample collection. Look at the general features of the regolith in road cuttings and other exposures. Make notes about any variations you see along the roads you travel on. Note the relationships between regolith and other physical features such as rock type, slope angles, landform types, erosion types, and vegetation or landuse.

2.2.4 Regolith Profile Observations

Obtaining information about the regolith at depth can be a problem. Deep exposures, especially those more than 2 m deep, should be studied whereever possible. Examples of such exposures are road cuttings, stream banks, gullies, and mine pits. Alternatively, drilling may be used, and some information can be obtained from shallow seismic data. Ground penetrating radar offers a new and as yet largely untried source of data about the regolith.

Deep exposures are by far the best source of information about the third dimension of regolith. Core or loose samples from drill holes can only rarely be identified as a particular regolith type. Drill cores should be used only as a last resort. It is better to extrapolate from known regolith terrain types, using surface features, particularly landforms, as a guide. Moreover, data from techniques such as seismic profiling and and ground penetrating radar can only be interpreted in light of information gained from study of good exposures. Their location in the landscape should be noted, and the details of any layering, weathering features etc. should also be noted.

2.2.5 Site Data Entry

The RTMAP database has a series of entry screens for this site data, and we have produced a summary data form for field use (Figure 2.2). Site data forms can be printed and bound into a convenient field notebook.

The left side of the site data form is for information about the site as a whole. The right side is for individual layers, or zones, at the site. Where there are several zones at a single site, a new form is used for each zone. However, site data need be entered only once. Details about completing the site data are given in Chapters 3 and 4.

2.3 DATA ENTRY AND MAP PRODUCTION

2.3.1 Entering Regolith Terrain Unit Data

If possible the Regolith Terrain Unit data should be completed before you leave the field, either on cards or entered into the computer. The reason for this is very simple. When you are in the field, you have all the available information, and especially the landscape, with you in a way you can never have when you return to the office. Any decisions about location of boundaries, and inclusion or exclusion of areas in various units, must be made in the field camps and preferably as soon as possible following the observations. It is no good thinking that extra time will allow better decisions on these things. It won't! The only thing that will happen is you will forget essential details. Do it immediately, while you still have all the information on hand. Once back at the office, all data should be entered into RTMAP, and checked for accuracy. Data entry is explained in Lenz (1991).

2.3.2 Preparation of Map

The same rules apply here. You should do as much as possible to finalise the draft map before leaving the field camps. It is much more difficult to check problem areas once you have returned to the central office.

The draft map should be finished, and entered into the GIS. Details of final map preparation on the GIS will be dealt with in another report.

Site ID: ....Date: ....ExpTyp: ....
1:250 000 map:S ...../........ 1:100 000 ....
Grid reference: E: ....N: ....
Elevation: ....Slope: ....Aspect: ....
Descriptive location: ....
....
Landform: ....
Geomorph. Process: ....
....
Bedrock Strat Name: ....
Bedrock Lithology: ....
Hazards: ....
Soil: ....
....
....
Vegetation: ....
....
....
Comments: ....
....
....
Abstract: ....
....
....
Photos: ....
....
Cross references: ....
....
Sketch: ....

Figure 2.2: RTMAP site data form.

Zone: . . . . . . Tkns: . . . . .Depth: . . . .
On fresh bedrock?: . . . Minerals? . . . .
. . . .
Boundary: . . . .
Colour: . . . .
. . . .
Mottles: . . . .
Nodules: . . . .
. . . .
. . . .
Matrix: . . . .
. . . .
. . . .
Grain size: . . . . Sorting: . . . . Clasts: . . . .
. . . .
. . . .
Regolith Type: . . . .
Induration: . . . .
Beds: Thickness: . . . . . Internal: . . . .
Comments: . . . .
. . . .
. . . .
Fabric: . . . .
. . . .
. . . .
Weathering: Degree: . . . . .Structures: . . . .
. . . .
. . . .
Veins: . . . .
Remarks: . . . .
. . . .
. . . .
Weathering processes: . . . .
. . . .
Geomorphic processes: . . . .
. . . .
Samples: . . . .
. . . .
Name/informal ID: . . . .

Figure 2.2: RTMAP site data form (contd).

In this chapter we provide comments on attributes which can be used as a reference when entering data into RTMAP, either directly, or via hard copy forms. We also provide lists of allowable entries for a number of attributes. These lists are the "authority tables" used in RTMAP. In these cases, RTMAP will accept only entries from the authority tables. Where users find situations where the authority tables are incomplete, they should contact the BMR Regolith Group with a view to adding an entry to the appropriate authority table. A full discussion and definitions of the attributes are found in Chapter 4.

In RTMAP, as in any database, data are entered into locations called fields. These fields are fixed in length. A few of the fields are manditory, and must be filled in, but most are optional. Details of field names and lengths, and whether they are optional or not, are found in Lenz (1991). Figures 3.1 and 3.2 show the simplified logical relationships of mapping unit data and field site data in RTMAP.

Where appropriate we have used the classifications found in the *Australian Soil and Land Survey Field Handbook* (McDonald *et al.* 1990). We have done this because that handbook is now well established as an authority for land and soil surveys. However, in most cases we have changed the codes to allow easier searches and reporting using ORACLE. In the above handbook, the codes are simply derived from the first letters of the class. In RTMAP we have arranged attributes into hierarchical order, to allow grouping of attributes. For example, to retrieve Regolith Terrain Units containing low hills the code ER30 would be used. However, to retrieve RTUs with all kinds of erosional landforms, the code ER% would be used (% is a wildcard character in ORACLE).

The two most important entities within RTMAP are the regolith terrain mapping unit (UNIT) and the site (SITE). The regolith ter-

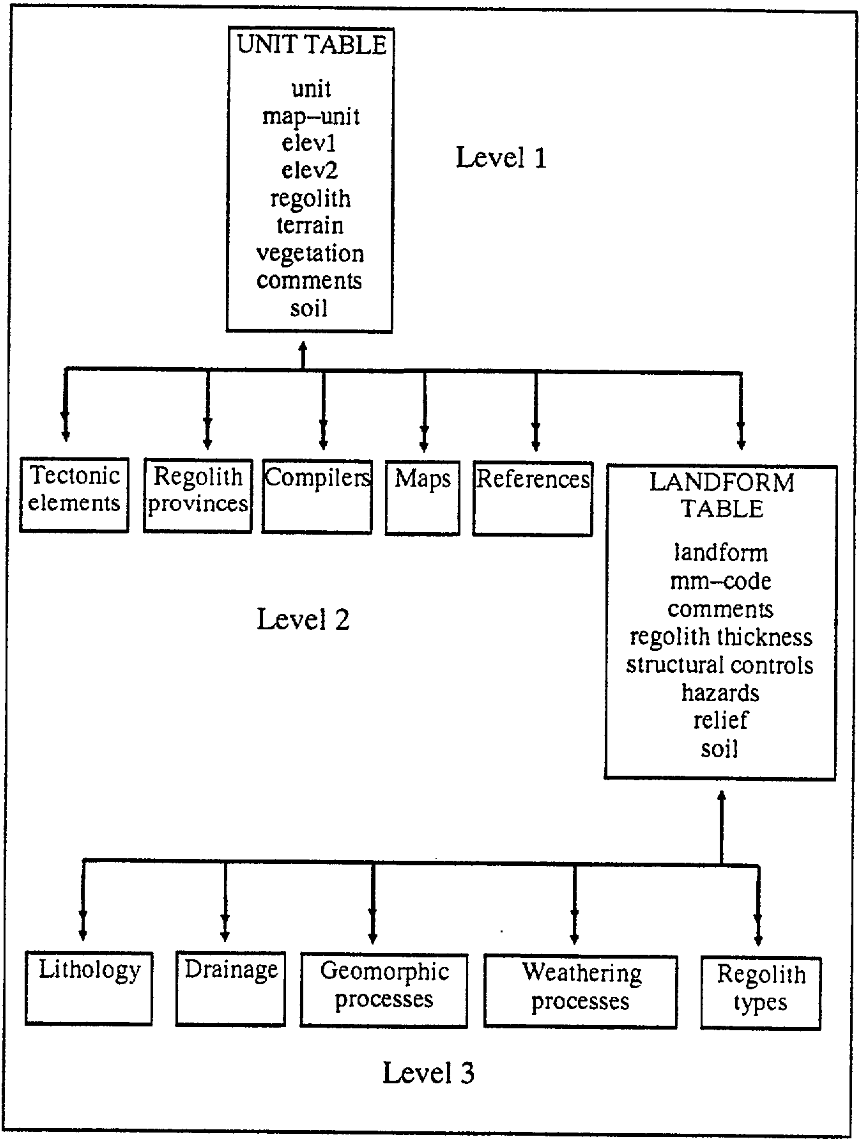


Figure 3.1. Simplified logical relationships of mapping unit data in RTMAP. Level 2 data have a many to one relationship to level 1 data, and level 3 data have a many to one relationship to level 2 data.

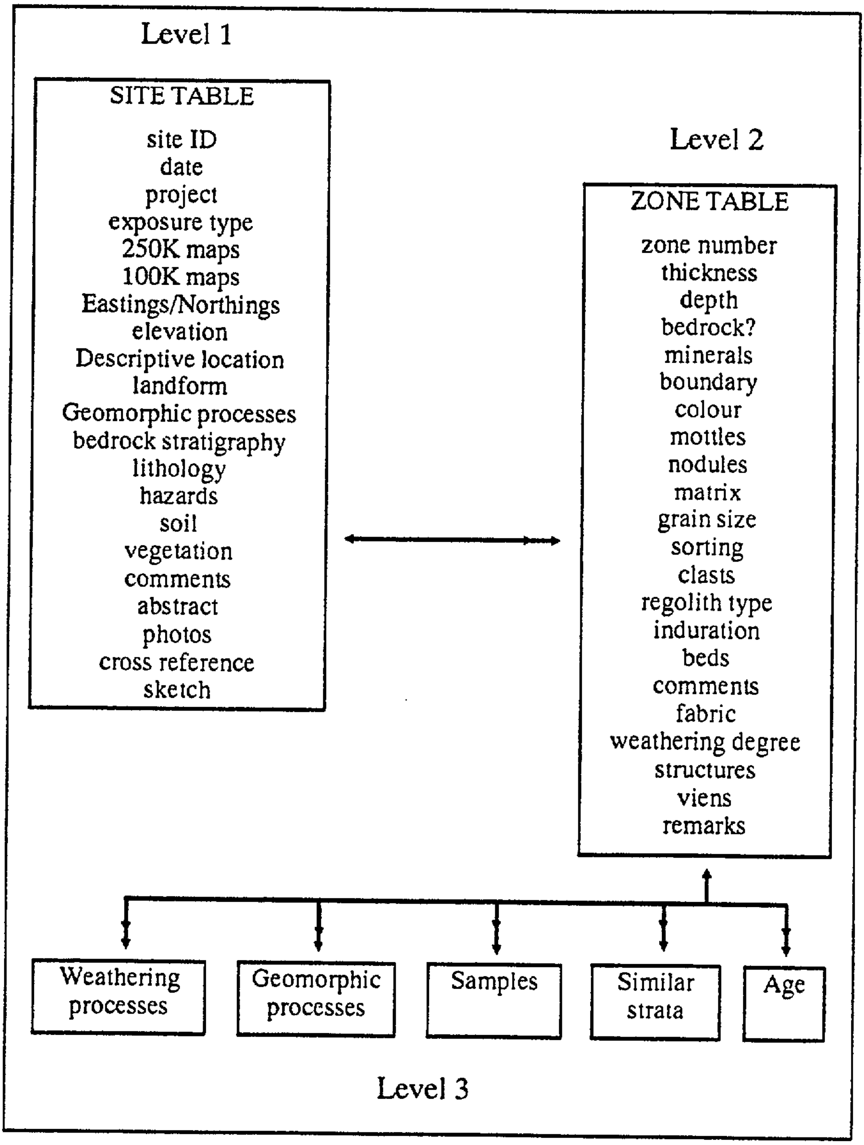


Figure 3.2: Simplified logical relationships of field site data in RTMAP. Level 2 data have a many to one relationship to level 1 data, and level 3 data have a many to one relationship to level 2 data.

rain mapping unit can combine horizontally more than one landform type and several regolith types. The site occurs in one landform type, but can be made up of several regolith types. Each regolith type may have several zones vertically. These many–to–one relationships are noted below where appropriate. Information from SITE data can help with compilation of UNIT data.

The attributes are dealt with in the order in which they appear on the data entry screens.

3.1 REGOLITH TERRAIN UNIT DATA

3.1.1 General Unit Data

These fields contain elevation and relief information about the regolith terrain unit and descriptive information about regolith, terrain, vegetation and soils. They refer to the whole unit, and not just part of it.

3.1.1.1 Unit ID

This is a unique automatically created sequential number cued by data entry. It is the number which identifies the regolith terrain unit in RTMAP, and it links all the tables together.

3.1.1.2 Map Unit

This is a unique number entered by the compiler at the time of map compilation. It corresponds to a polygon or number of polygons on the map face, and is necessary to link the map in the GIS to the data entry in RTMAP.

3.1.1.3 Elevation

Enter the lower and upper values of the elevation range for the whole unit.

3.1.1.4 Terrain, Regolith and Vegetation

These are free text fields for descriptions of terrain, regolith and vegetation within the unit as a whole.

3.1.1.5 General Unit Comments

This field is for any comments about the unit which cannot be entered elsewhere in the database.

3.1.1.6 Soils Comments

Enter summary information at a general unit level in this field. If the information about soils is detailed enough, relate the soil type to the landform unit by using the soil field on the landform unit description sheet or screen.

The amount of soils information that can be entered will depend to a large extent on the observer. Those with knowledge of a soil classification system (e.g. Northcote Key, Great Soil Groups, or the new Australian Soil Taxonomy) should use it. Appropriate codes are listed in Chapter 4. Others should note only the main morphological features of the soil.

The following fields may have many to one relationships to the Regolith Terrain Unit.

3.1.1.7 Tectonic Elements

Enter one or more elements from the Tectonic Elements Table. This table lists the 93 tectonic structural elements, and corresponding number codes, of Australia, from Palfreyman (1984) (Figure 3.1).

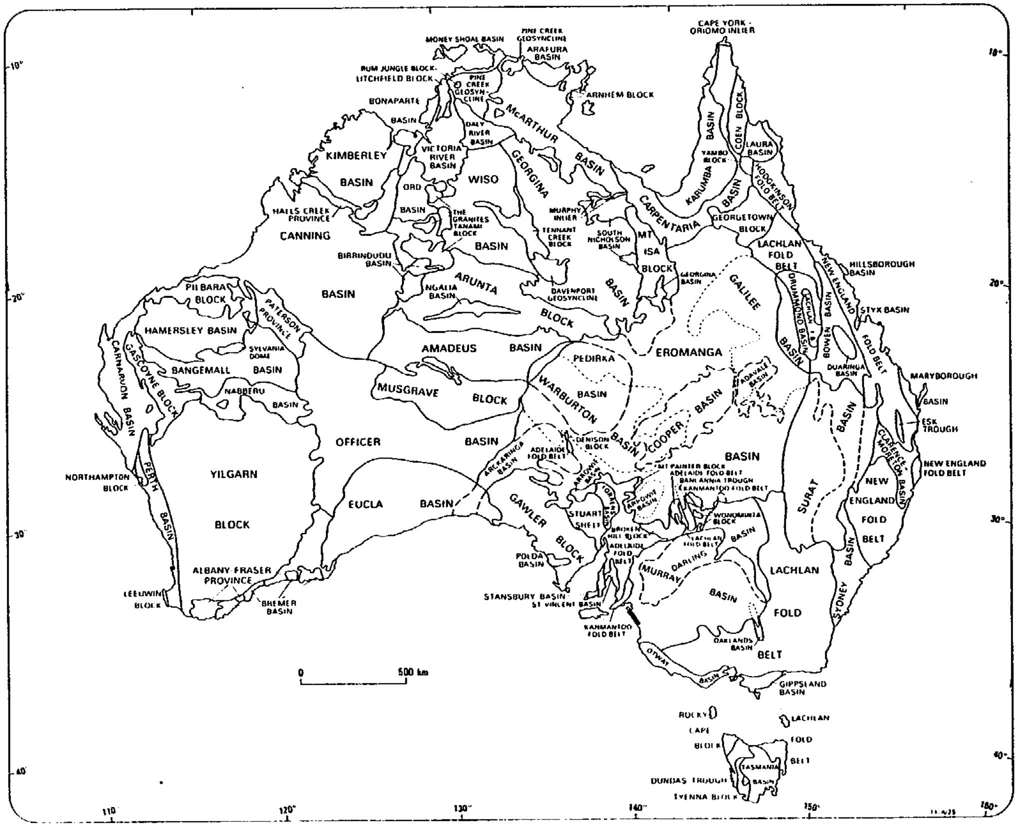


Figure 3.3. Tectonic Structural elements of Australia (Palfreyman 1984)

01	Adavale Basin	43	Hodgkinson Fold Belt
02	Adelaide Fold Belt	44	Kanmantoo Fold Belt
03	Albany–Fraser Province	45	Karumba Basin
04	Amadeus Basin	46	Kimberley Basin
05	Arafura Basin	47	Lachlan Fold Belt
06	Arckaringa Basin	48	Laura Basin
07	Arnhem Block	49	Leeuwin Block
08	Arrowie Basin	50	Litchfield Block
09	Arunta Block	51	Maryborough Basin
10	Bancannia Trough	52	McArthur Basin
11	Bangemall Basin	53	Money Shoal Basin
12	Birrindudu Basin	54	Mount Isa Block
13	Bonaparte Basin	55	Mount Painter Block
14	Bowen Basin	56	Murphy Inlier
15	Bremer Basin	57	Murray Basin
16	Broken Hill Block	58	Musgrave Block
17	Canning Basin	59	Nabberu Basin
18	Cape York–Oriomo Inlier	60	New England Fold Belt
19	Carnarvon Basin	61	Ngalia Basin
20	Carpentaria Basin	62	Northampton Block
21	Clarence–Moreton Basin	63	Oaklands Basin
22	Coen Block	64	Officer Basin
23	Cooper Basin	65	Ord Basin
24	Daly River Basin	66	Otway Basin
25	Darling Basin	67	Paterson Province
26	Davenport Geosyncline	68	Pedirka Basin
27	Denison Block	69	Perth Basin
28	Drummond Basin	70	Pilbara Block
29	Duaringa Basin	71	Pine Creek Geosyncline
30	Dundas Trough	72	Polda Basin
31	Eromanga Basin	73	Rocky Cape Block
32	Esk Trough	74	Rum Jungle Block
33	Eucla Basin	75	South Nicholson Basin
34	Galilee Basin	76	Stansbury Basin
35	Gascoyne Block	77	Stuart Sheld
36	Gawler Block	78	St Vincent Basin
37	Georgetown Block	79	Styx Basin
38	Georgina Basin	80	Surat Basin
39	Gippsland Basin	81	Sydney Basin
40	Halls Creek Province	82	Sylvania Dome
41	Hamersley Basin	83	Tasmania Basin
42	Hillsborough Basin	84	Tennant Creek Block

85	The Granites–Tanami Block	89	Warburton Basin
86	Torrens Basin	90	Wiso Basin
87	Tyenna Block	91	Wonominta Block
88	Victoria River Basin	92	Yambo Block
		93	Yilgarn Block

3.1.1.8 Regolith Terrain Provinces

This field is for Regolith Terrain Province names, from the Table PROV. The Province details are followed by the major/subordinate (M/S) code to indicate if the Regolith Terrain Unit is a major or subordinate component within the Regolith Terrain Province. To date Regolith Terrain Provinces have been identified only for the Kalgoorlie 1:1 000 000 sheet.

3.1.1.9 Compiler Details

Enter the compiler's name, affiliation, and date of compilation (e.g. Pain, C F, BMR). The BMR list, with number codes, is as follows:

01 Chan, R A, BMR
02 Craig, M A, BMR
03 Dohrenwend, J C, USGS
04 Gozzard, R, GSWA
05 Grimes, K, GSQ
06 Hazell, M, BMR
07 Kamprad, J L, BMR
08 Ollier, C D, UNE
09 Pain, C F, BMR
10 Wilford, J, BMR

3.1.1.10 Map

The map code for maps used as references for compiling the RTU data can be entered here. Map name and scale will be displayed on the screen in response. Full information is contained in the table MAPS. The map code consists of a letter symbol identifying the category of map used (T = topographic, S = soils, G = geologic, V = vegetation, L = land systems, O = other) plus a sequential number within each category. The BMR list is available on request.

3.1.1.11 Reference and Author

This field is for information about bibliographic references. A ref(erence) number code is entered and the author(s) and date of publication will be displayed on the screen in response. Full information is contained in the table REFS. The number code is a sequential system–generated number. The BMR list is available on request.

3.1.2 Landform Unit Data

There may be many landform units within one Regolith Terrain Unit. The following fields are completed for each landform unit (Figure 3.1).

3.1.2.1 Landform

Enter the landform code followed by the major/subordinate (M/S) code to indicate if the landform unit is a major or subordinate component of the Regolith Terrain Unit. The landform code comes from the Landform Table.

AL00	alluvial landforms
AL10	alluvial plain
AL11	flood plain
AL12	anastomotic plain
AL13	bar plain
AL14	covered plain
AL15	meander plain
AL20	alluvial terrace
AL30	stagnant alluvial plain
AL40	terraced land
AL50	alluvial swamp

CO00	coastal lands	
CO01		beach ridges
CO02		chenier plain
CO03		coral reef
CO04		marine plain
CO05		tidal flat
CO06		coastal dunes
DE00	delta	
DU00	dune field	
DU01		longitudinal dune field
ER00	erosional landforms	
ER10		erosional plain (< 9 m relief)
ER11		pediment
ER12		pediplain
ER13		peneplain
ER14		etchplain
ER20		rises (9 – 30m relief)
ER30		low hills (30 – 90m relief)
ER40		hills (90 – 300m relief)
ER50		mountains (> 300m relief)
ER60		escarpment
ER70		badlands
ER80		drainage depression
FA00	fan	
FA01		alluvial fan
FA02		colluvial fan/footslope
FA03		sheet–flood fan
KA00	karst	
MA00	made land	
ME00	meteor crater	
PL00	plain	
PL01		depositional plain
PL02		lacustrine plain

PL03		playa plain
PL04		sand plain
PT00	plateau	
VO00	volcano	
VO01		caldera
VO02		cone (volcanic)
VO03		lava plain
VO04		ash plain

3.1.2.2 Relief

Enter here the average local relief, the difference in elevation between the highest and lowest parts of the landform unit. (This should not be confused with elevation, which is absolute height above sea level.)

3.1.2.3 Structural Controls

The type of structural control on landforms in the landform unit is given from the following list, with their codes.

NS	no structural control
AN	anticline
AD	anti dip slopes
BF	block faulting
CU	cuesta forms
DB	dipping beds
DI	dip slope
DS	dyke/sill
FT	faulted
HG	horst/graben
HO	horizontal bedding
JN	jointing
MN	monocline
SA	strike aligned
SN	syncline

3.1.2.4 Environmental Hazards

If the landform unit is susceptible to any environmental hazards, either make a brief comment in this field, or enter a code from the following list:

NH no recognised hazards

AV snow avalanche
CO coastal erosion
CP coastal progradation
FF flash flood
FL flood
LA landslide
RO rockfall
SA salinity
SC solution cavities
SD sand drift
SO soil erosion
ST storm surge
SU subsidence
TS tsunami
VE volcanic eruption

3.1.2.5 Regolith Thickness

Regolith thickness over an entire RTU is impossible to determine. This field is for a general indication of the maximum thickness of regolith in an RTU. An arbitrary value of 2 m distinguishs bedrock dominated terrains from weathering or sediment dominated terrains. Enter a thickness code from the following list:

0 unknown
1 < 0.5 m
2 < 2 m
3 > 2 m
4 > 5 m
5 > 15 m
6 > 50 m

3.1.2.6 Comments on Soil

See comments in section 3.1.1.6. Use this field only if the soil information can be related to the landform unit.

3.1.2.7 Comments on Landform

This is a comments field for free–text description of the landform within the unit. This could include depth and degree of dissection, if appropriate.

The following fields have a many to one relationship to the landform unit. For each landform unit, complete the following fields as many times as necessary to cover the range of attributes (Figure 3.1).

3.1.2.8 Lithology

The lithology code stands for the lithology of the bedrock below this particular landform unit. There may be more than one lithologic type under a single landform unit. The lithology code comes from the following table, which is the list of lithology types from the Queensland Department of Resources Industry's REGMAP (Lang *et al.* 1990). We have rearranged the REGMAP list into a hierarchical order, and assigned new codes.

Lithologies	RTMAP Codes	REGMAP Codes
unknown	UN000	–
igneous rock	IGROCK	–
igneous intrusive rock	INTRUS	–
felsic igneous intrusive	INFELS	–
felsite	INFLST	FLST
granite	INFGRN	GRNT
adamellite	INFADM	ADML
granodiorite	INFGRD	GRDI
aplite	INFAPL	APLT
microgranite	INFMCG	MCGR

microgranodiorite	INFMGD	MCGD
microgranitoid	INFMGT	MCGT
granotoid	INFGRT	GRTD
quartz diorite	INFQDI	QDIO
quartz porphry	INFQZP	QZPO
quartz feldspar porphry	INFQFP	QFPO
feldspar porphry	INFFSP	FSPO
tonalite	INFTON	TONL
alaskite	INFALS	ALSK
leucogranite	INFLCG	LCGR
leucogranitoid	INFLGR	LGRT
trondhjemite	INFTRO	TRON
pegmatite	INFPEG	PEGM
intermediate igneous intrusive	INIMED	-
diorite	INIDIO	DIOR
syenite	INISYE	SYEN
monzonite	INIMON	MONZ
microdiorite	INIMCD	MCDI
microsyenite	INIMCS	MCSY
micromonzonite	INIMCM	MCMZ
mafic igneous intrusive	INMAFC	-
gabbro	INMGBB	GBBR
dolerite	INMDOL	DOLR
serpentinite	INMSER	SERP
lamprophyre	INMLAM	LAMP
ultramafic igneous intrusive	INUMAF	-
pyroxenite	INUPXN	PXNT
peridotite	INUPRD	PRDT
dunite	INUDUN	DUNT
harzburgite	INUHAR	HARZ
clinopyroxenite	INUCPX	CPXT
chromitite	INUCRM	CRMT
mafic/ultramafic intrusive	INMUMF	-
igneous extrusive rock	IXTRUS	-
lava	IXTLAV	LAVA
volcanics	IXTVOL	VOLC
felsic igneous extrusive	IXFELS	-
rhyolite	IXFRHL	RHLT
obsidian	IXFOBS	OBSD
glass	IXFGLS	GLSS
dacite	IXFDAC	DACT
perlite	IXFPER	PERL
granophyre	IXFGRN	GRNP

pitchstone	IXFPCS	PCST
rhyodacite	IXFRHD	RHDA
intermediate igneous extrusive	IXIMED	–
andesite	IXIAND	ANDS
trachyte	IXITRA	TRAC
phonolite	IXIPHO	PHON
trachyandesite	IXITAN	TAND
mafic igneous extrusive	IXMAFC	–
basalt	IXMBSL	BSLT
keratophyre	IXMKPH	KPHR
nephelinite	IXMNEP	NEPH
trachybasalt	IXMTBA	TBAS
ultramafic igneous extrusive	IXUMAF	–
spilite	IXUSPL	SPIL
igneous extrusive ejecta	IXJCTA	–
scoria	IXJSCO	–
ash	IXJASH	–
tuff	IXJTUF	TUFF
agglomerate	IXJAGL	AGLM
ignimbrite	IXJIGN	IGNM
sedimentary rock	SDROCK	–
arenite	SDARNT	ARNT
argillite	SDARGL	ARGL
rudite	SDRUDT	–
siliciclastic sedimentary rock	SSCLTC	–
mudstone	SSMDST	MDST
shale	SSSHLE	SHLE
siltstone	SSSLST	SLST
sandstone	SSSDST	SDST
greywacke	SSGYWK	GYWK
arkose	SSARKS	ARKS
conglomerate	SSCGLM	CGLM
sedimentary breccia*	SSBREC	BREC
aeolinite	SSAEOL	–
claystone	SSCLST	CLST
orthoquartzite	SSOQTZ	OQTZ
subgreywacke	SSSGYW	SGYW
tillite	SSTILL	TILL
pelite	SSPELT	PELT
chemical/biogenic sedimentary rock	SCHBIO	–
limestone	SCLMST	LMST
dolomite	SCDLOM	DLOM

chert	SCCHRT	CHRT
jasper	SCJSPR	–
jaspilite	SCJASP	JASP
calcrudite	SCCLRD	CLRD
calcilutite	SCCALU	CALU
calcarenite	SCCAAR	CAAR
banded iron formation	SCBIFN	BIF
travertine	SCTRAV	TRAV
coal	SCCOAL	COAL
lignite	SCLGNT	LGNT
diatomite	SCDIAT	DIAT
micrite	SCMCRT	MCRT
grapestone	SCGPST	GPST
gypsum	SCGPSM	GPSM
marl	SCMARL	MARL
packstone	SCPKST	PKST
phosphorite	SCPHOS	PHOS
boundstone	SCBDST	BDST
coquinite	SCCOQT	COQT
grainstone	SCGSTN	GSTN
wackestone	SCWKST	WKST
mixed siliciclastic/(chemical/biogenic)	SXCBIO	
oil shale	SXOSHL	OSHL
metamorphic rock	MEMETS	METS
metasediment	MSMSED	MSED
meta–arenite	MSMARN	MARN
meta–greywacke	MSMGYW	MGYW
metapelite	MSMPEL	MPEL
metamorphic felsic igneous rock	MFELSC	–
metadacite	MFMDAC	MDAC
metarhyolite	MFMRHY	MRHY
greisen	MFGREI	GREI
metaporphry	MFMPOR	MPOR
metamorphic intermediate igneous rock	MINEDT	–
meta–andesite	MIMAND	MAND
metadiorite	MIMDIO	MDIO
metamorphic mafic igneous rock	MMAFIC	–
amphibolite	MMAMPH	AMPH
para–amphibolite	MMPAMP	PAMP
metabasalt	MMMBAS	MBAS
metadolerite	MMMDLR	MDLR
metagabbro	MMMGBR	MGBR

metamorphic ultramafic rock	MUMAFC	–
soapstone	MUSPST	SPST
chemical metamorphic rock	MCHEMR	–
metasomatite	MCSOMT	–
thermal metamorphic rock	MTHERM	–
hornfels	MTHFLS	HFLS
marble	MTMRBL	MRBL
skarn	MTSKRN	SKRN
regional metamorphic rock	MREGNL	–
slate	MRSLAT	SLAT
phyllite	MRPHYL	PHYL
schist	MRSCHT	SCHT
gneiss	MRGNSS	GNSS
migmatite	MRMIGM	MIGM
agmatite	MRAGMT	–
granulite	MRGRNL	GRNL
greenschist	MRGNSC	GNSC
greenstone	MRGNST	GNST
quartzite	MRQTZT	QTZT
calcsilicate rock	MECASI	CASI
dynamic metamorphic rock	MDYNMC	–
mylonite	MDMYLN	MYLN
fault breccia*	MDFBRC	BREC
cataclasite	MDCATA	CATA
gouge	MDGOUG	GOUG

* The Regmap breccia data type is undefined and appears in our list next to sedimentary breccia and fault breccia.

The following Regmap LITH data types have not been given RTMAP codes. In RTMAP, these materials are included in the Regolith Type table.

alluvium	ALLV
caliche	CACH
colluvium	CLLV
concretion	CONC
ferricrete	FECT
gossan	GOSS
gravel	GRVL
gypsum	GPSM
ironstone	FEST
laterite	LATR

limonite	LIMT
pseudoconglomerate	PSCG
silcrete	SICT
silt	SILT
soil	SOIL
wood	WOOD

Lithology Details: There is also a 30 character field which can be used to further describe the lithology, if necessary.

Stratigraphy and Age: If the stratigraphic relationships are known, enter the stratigraphic details. In most cases this can be obtained from a geology map. Where the data is being displayed on a GIS, the stratigraphic nomenclature and lithology of the bedrock will form a separate layer.

3.1.2.9 Drainage

There are 5 fields relating to drainage. These are the drainage pattern, the major/subordinate (M/S) code, drainage character, drainage type, and stream channel spacing. Codes are obtained from the following lists:

Drainage Pattern

NA none

AB anabranching
AG angulate
AN annular
BA barbed
CP centripetal
CR circumvolcanic
CV convergent
DN dendritic
DS distributary
DV divergent
GU gutter
IN interrupted

PA	parallel
RA	radial
RC	rectangular
TR	trellis

Drainage Character

D	dry
I	intermittent
P	perennial

Drainage Type

A	anticedent
C	captured
D	diverted
N	normal
R	reversed
S	superimposed
U	underground

Stream Channel Spacing

AB	Absent or very rare	> 2500 m
SP	Sparse	1500 – 2500 m
VW	Very widely spaced	1000 – 1500 m
WS	Widely spaced	625 – 1000 m
MS	Moderately spaced	400 – 625 m
CS	Closely spaced	250 – 400 m
VC	Very closely spaced	150 – 250 m
NU	Numerous	< 150 m

3.1.2.10 Geomorphic Processes

Enter the geomorphic process, the major/subordinate (M/S) code, and the active or relict (A/R) code. The active code allows present day processes to be recorded, while the relict code allows recognition of processes active in the past that were responsible for the origin of the landform unit. The geomorphic process code comes from the following table:

GR00	gravity
GR01	vertical collapse
GR02	particle fall
GR03	creep
GR04	landslide
GR05	mudflow
WT00	water
WT01	channelled stream flow
WT02	over–bank stream flow
WT03	sheet flow, sheet wash, surface wash,
WT04	waves
WT05	tides
WT06	detrital deposition in still water
WT07	rilling/gullying
WT08	subsurface solution/piping
IC00	ice
IC01	frost
IC02	glacial erosion
IC03	glacial deposition
WI00	wind
WI01	wind erosion (deflation)
WI02	sand deposition
WI03	dust deposition
DI00	diastrophism; earth movements
VO00	volcanism
VO01	lava flow
VO02	ash flow
VO03	ash fall
BI00	biological agents; coral
HU00	human agents
MT00	impact by meteors

3.1.2.11 Weathering Processes

Enter the weathering processes, the major/subordinate (M/S) code, and the active or relict (A/R) code. The active code allows present day weathering processes to be recorded, while the relict code allows recognition of weathering processes active in the past. The weathering process code comes from the following table:

WE00	weathering
PH00	physical weathering
PH01	abrasion
PH02	frost weathering
PH03	induced fracture
PH04	insolation weathering
PH05	moisture swelling
PH06	sheeting
PH07	salt weathering
PH08	volume increase
PH09	wetting and drying
CH00	chemical weathering
CH01	solution
CH02	oxidation and reduction
CH03	carbonation
CH04	hydration
CH05	chelation
CH06	hydrolysis
CH07	ferrolysis
CH08	chemical precipitation/evaporation
IN00	induration
IN01	bauxitic induration
IN02	calcareous induration
IN03	clay induration
IN04	ferruginous induration
IN05	gypsiferous induration
IN06	siliceous induration
HA00	hydrothermal alteration

BI00	biotic weathering

3.1.3 Regolith Type Data

3.1.3.1 Regolith Type

Enter the code for regolith type in this field, and the major/subordinate (M/S) code. The regolith type code comes from the following table:

WMU00	weathered material (unknown origin)
WIR00	in situ weathered rocks
WIR10	deep weathered regolith
WIR11	saprolite
WIR12	structured saprolite
WIR13	mottled zone
WIR14	pallid zone
WIR20	residual material
WIR21	lag
WIR22	residual sand
WIR23	residual clay
WIR24	soil on fresh bedrock
UOS00	sand (unknown origin)
UOC00	clay (unknown origin)
SDT00	terrestrial sediments
SDA00	alluvial sediments
SDA10	channel deposits
SDA20	overbank deposits
SDC00	colluvial sediments
SDC01	scree
SDC02	landslide deposit
SDC03	mudflow deposit
SDC04	creep deposit
SDC05	sheet flow deposit
SDC06	fanglomerate

SDE00	aeolian sediment
SDE01	aeolian sand
SDE02	loess
SDE03	parna
SDS00	coastal sediments
SDS01	beach sediments
SDS02	estuarine sediments
SDL00	lacustrine sediments
SDM00	marine sediment
SDG00	glacial sediments
SDF00	fill
VOL00	volcanic material
VOL01	lava flow
VOL02	ash
EVA00	evaporite
EVA01	halite
EVA02	gypsum
IND00	indurated material
IND10	bauxitic induration
IND20	calcareous induration
IND30	clay induration
IND40	ferruginous induration
IND50	gypsiferous induration
IND60	siliceous induration
IND70	humic induration
IDU00	duricrust
IDS00	completely cemented duricrust (crete)
IDS10	alcrete (bauxite)
IDS20	calcrete
IDS40	ferricrete
IDS41	massive ferricrete
IDS42	nodular ferricrete

IDS50	gypcrete
IDS60	silcrete
IDM00	moderately cemented duricrust
IDM20	calcareous duricrust
IDM40	ferruginous duricrust
IDM60	siliceous duricrust
IDP00	partially cemented duricrust (hardpan)
IDP30	clay hardpan
IDP60	siliceous hardpan
IDP70	humic hardpan
INO00	nodules
INO10	bauxitic nodules
INO20	calcareous nodules
INO30	clay nodules
INO40	ferruginous nodules
INO60	siliceous nodules

3.1.3.2 Degree Of Weathering

The degree of weathering code can be used to modify regolith types. In cases where indurated material has been chosen as the regolith type, a degree of weathering code would not normally be entered. Degree of weathering is chosen from the following list:

0	unknown
1	unweathered
2	slightly weathered
3	moderately weathered
4	highly weathered
5	very highly weathered
6	completely weathered

3.1.3.3 Induration

Codes for the induration field come from the regolith types table. The induration field is used if the regolith material, prior to it being indurated, is known. In this case it acts as modifier to the regolith type which is entered into the regolith type field. In many cases, however, the parent material is obscured by the induration, making its identification impossible. In these cases the type of induration is selected as the regolith type and entered in the regolith type field. The induration field would be left empty.

3.1.3.4 Thickness

This thickness entry is for specific regolith types. The thickness entry in section 3.1.2.5 refers to general regolith thickness in the landform unit as a whole.

0	unknown
1	< 0.5 m
2	< 2 m
3	> 2 m
4	> 5 m
5	> 5 m
6	> 50 m

3.1.3.5 Informal Age

The age fields are completed if the regolith type has been dated or an age inferred from work done. The ages can be entered as a range, or as a single age entered into the first field if there is no age range. Ages are entered as full names, e.g. Pliocene, or Cretaceous, and may include prefixes, e.g. Upper, Middle etc.

There is a field for comments about age which can be used for details on how the age was obtained, whether it is a maximum or minimum age, and its accuracy.

3.1.3.6 Regolith Profile

This is a descriptive field for recording the total known gross profile characteristics of the regolith, including any truncation or covering that may have occurred.

3.1.3.7 Regolith Distribution

This is a descriptive field for comments on the 3 dimensional landscape position of the regolith type. It can be used to describe any toposequence relationships observed in the regolith type.

3.2 SITE DATA

These fields contain information about individual sites that are studied in detail (Figure 3.2). Comments on the selection of field sites is given in Chapter 2. In practice they will be chosen on the basis of availability. We will not describe in detail a field site for each RTU. At a reconnaissance level of mapping this is neither possible nor necessary.

3.2.1 General Site Data

This group of database fields describes a field site and contains identifying information, locational data and descriptive information on various aspects of the site.

3.2.1.1 Number

This is a unique identifier which can have up to 7 letters or numbers. It is made up of three parts. The first letter gives the organisation; for BMR this is Z. The next two characters are the compiler's initials, and the remaining four characters are numbers. This system is adopted from REGMAP, and is used in other geological mapping at BMR.

3.2.1.2 Date

This is the date of data collection in the field.

3.2.1.3 Project

This is an abbreviation for the project name.

3.2.1.4 Exposure type

The type of site is selected from the following list:

AUGER	Auger hole (soil/otherwise)
CANAL	Canal
CLIFF	Cliff
CORE	Core
COST	Costean
CUTTI	Cuttings
DAM	Dam
FLOAT	Float
GRAVE	Gravel scrape
GULLY	Gully (for gullies/washouts)
MINE	Mine
OUTCR	Outcrop
PROSP	Prospect
QUARR	Quarry
RAILW	Railway
ROAD	Road/highway cutting
RUBBL	Rubble
SOIL	Soil
STREA	Stream (for creeks/rivers)
TRENC	Trench

3.2.1.5 Map1 and Map2

These two fields are for the 1:250 000 map (format: S55/13) and the 1:100 000 map number (4 digits).

3.2.1.6 East and North

These two fields are for AMG map coordinates.

3.2.1.7 Elevation, Slope and Aspect

These fields are for elevation in metres, slope angle in degrees (0 – 90) and aspect in degrees (0 – 360).

3.2.1.8 Descriptive Location

This field is used for any details of the site location.

3.2.1.9 Landform

Enter a code for landform type from the landform table.

3.2.1.10 Geomorphic Process

The geomorphic process code comes from the geomorphic process lookup table. There is space for 2 codes, for the main and a less dominant geomorphic process.

3.2.1.11 Bedrock Stratigraphic Name

This is for the bedrock stratigraphic unit which underlies the regolith at this site, if known. Stratigraphic units are given a code from the STRAT table in RTMAP.

3.2.1.12 Bedrock Lithology

Enter the code, from the lithology lookup table, for the bedrock lithology underlying the regolith at this site, if known.

3.2.1.13 Hazard

This is used for comments on environmental hazards. A code from the list of hazards in 3.1.2.4 may be used here.

3.2.1.14 Soil

This field is for a description of the soil at the site.

3.2.1.15 Vegetation

This field can contain a description of the vegetation at the site.

3.2.1.16 Comments

This is a free text field for any other comments about the site as a whole.

3.2.1.17 Abstract

The abstract field is for a summary description of the site, including brief comments about the zones.

3.2.1.18 Photos

Record details of photos taken at this site here.

3.2.1.19 Cross References

This field is for references to similar sites.

3.2.1.20 Sketch

Enter a Y here if a sketch was made of this site during field data collection.

3.2.2 Zone Data

The following fields contain information about a single vertical zone, or layer, within a field site. Usually there will be several zones at each field site.

3.2.2.1 Zone Number

The zone number is a 2–digit number in the format 01, 02, 03 etc., increasing with depth from surface.

3.2.2.2 Thickness

This is a number field for the average thickness of the zone, in the format: 3 digits, decimal point, 2 digits, given in metres.

3.2.2.3 Depth

Enter the depth of the lower boundary of the zone in metres (2 decimals allowed).

3.2.2.4 Bedrock

Enter a Y if there is bedrock immediately below this zone.

3.2.2.5 Mineralisation

This is for any noteworthy mineralisation, and can be entered as a code from REGMAP's mineral table, given here.

actinolite	ACT	anhydrite	ANHY
agate	AE	anorthite	AN
albite	AB	anorthoclase	ANOR
alunite	ALU	anthophyllite	APHY
amphibole	AMPH	apatite	AP
andalusite	ANDL	aragonite	ARAG
anglesite	ANGT	arsenopyrite	ASPY

augite	AUG	kaolin/kaolinite	KAO
azurite	AZ	kyanite	KY
barite	BA	limonite	LIM
bauxite	BX	magnestite	MS
bentonite	BENT	magnetite	MT
biotite	BI	malachite	MAL
bismuthinite	BIS	mica	MI
bornite	BN	molybdenite	MOL
calcite	CALC	muscovite	MUS
cassiterite	CST	natrolite	NAT
cerargyrite	CRG	nepheline	NEP
chabazite	CHAB	olivine	OLN
chalcedony	CHDY	opal	OP
chalcocite	CC	orthoclase	OR
chalcopyrite	CPY	orthopyroxene	OPX
chlorite	CHL	plagioclase	PLAG
chloritoid	CHD	potash feldspar	KFS
chromite	CR	prehnite	PREH
chrysocolla	CHYC	pyrite	PY
clay	CY	pyroxene	PX
clinopyroxene	CPX	pyrrhotite	PYRH
clinozoisite	CLIZ	quartz	Q
cordierite	CORD	sanidine	SAN
covellite	CV	sapphire	SAPP
cummingtonite	CUMM	scapolite	SCAP
cuprite	CUP	scheelite	SCHE
diopside	DI	sericite	SER
dolomite	DO	serpentine	SERP
epidote	EPD	siderite	SID
feldspar	FS	sillimanite	SILL
fluorite	FL	smithsonite	SMN
galena	GAL	sphalerite	SPL
garnet	GA	staurolite	STAU
glauconite	GL	sphene	SPN
goethite	GOET	stibnite	STIB
graphite	GT	talc	TC
gypsum	GYP	topaz	TPZ
hematite	HEM	tourmaline	TOUR
hornblende	HB	tremolite	TREM
iddingstite	IDD	vesuvianite	VSV
ilmenite	IM	wavellite	WV
jarosite	JAR	wolframite	WOLF

3.2.2.6 Boundary

Enter a description of the character of the lower boundary (e.g. smooth, wavy, irregular, sharp, abrupt, clear, gradual, diffuse, weathering, conformable, angular unconformity, disconformity, paraconformity, nonconformity, etc.).

3.2.2.7 Colour

This field can be used for any free–text descriptions of colour, colour changes or combinations.

3.2.2.8 Mottling

This field is used for comments about any mottling present, including size, abundance, contrast with surrounding material, and strength or induration.

3.2.2.9 Nodules

This field is used for comments about any nodules present, including size, abundance, contrast with surrounding material, and strength or induration.

3.2.2.10 Matrix

This is a text field for a description of the matrix of the zone.

3.2.2.11 Grain size

Enter the size of particles in the zone, from the following list:

CL	clay	
SI	silt	
SA	sand	(< 2 mm)
GR	gravel	(2 – 60 mm)
CO	cobbles	(60 – 200 mm)

ST	stones	(200 – 600 mm)
BO	boulders	(> 600 mm)

3.2.2.12 Sorting

Describe the particle sorting:

W	well sorted,
M	moderately sorted,
P	poorly sorted,
B	bimodal sorting,
U	unsorted.

3.2.2.13 Clasts

In this text field describe other characteristics of the > 2 mm fraction, particularly whether particles are clast or matrix supported, rounding, abundance, strength, lithology etc.

3.2.2.14 Regolith Type

This field is for the regolith type, and comes from the regolith type lookup table.

3.2.2.15 Induration

This field is for the degree and type of induration and comes from the regolith type look–up table.

3.2.2.16 Bedding Thickness

Enter a code from the following list:

LA	laminated	(< 1cm)
VN	very thin beds	(1 – 3 cm)
TN	thin beds	(3 – 10 cm)
MB	medium beds	(10 – 30 cm)

TK	thick beds	(30 – 100 cm)
VK	very thick beds	(> 100 cm)

3.2.2.17 Internal Bedding

This field contains a code from the following list:

MA	massive
LA	laminations
XX	cross bedding
BD	bidirectional bedding
NG	normal graded bedding
RG	reverse graded bedding
HO	horizontal bedding
BL	blanket bedding
OT	other bedding types

3.2.2.18 Bedding Comments

This is a free–text field for any comments on the bedding.

3.2.2.19 Fabric

This field is for comments on the fabric of the zone, including orientation of particles and any indications of flow direction.

3.2.2.20 Weathering

This is for the degree of weathering:

0	unknown
1	unweathered
2	slightly weathered
3	moderately weathered
4	highly weathered
5	very highly weathered
6	completely weathered

3.2.2.21 Weathering Structures

This is a free text field is for any comments about weathering characteristics of the zone.

3.2.2.22 Veins

This field is for comments about any veins present.

3.2.2.23 Remarks

This field is for any free–text additional comments pertaining to the zone.

3.2.2.24 Weathering Processes

This field is for a code from the Weathering Processes table. It is used for weathering processes responsible for the formation of the zone.

3.2.2.25 Geomorphic Processes

This field is for a code from the Geomorphic Processes table. It is used for geomorphic processes responsible for the formation of the zone.

3.2.2.26 Samples

The following fields relate to samples taken in the field:

Site ID is the site identifier, and is carried over from the zone description. *Zone Number* is also carried over.

Sample Number is a sequential number.

BMR Identification contains the identification for sample numbers (two digits for the current year and the next two digits identify the Regolith Group: 99).

Sample Description contains any comments or description of the sample.

3.2.2.27 Similar Strata

Make a note in this field of zones at other sites which have similar characteristics. Both Site ID and Zone Number for the other sites should be entered. There is also a field that can be used for informal identifying names which might be applied to the zone.

3.2.2.28 Age Determination

If it has been dated, enter the absolute age of the zone in millions of years. There are three fields, Age, Range and Method.

4 ATTRIBUTE DEFINITIONS

In this chapter we have followed standard definitions where possible, especially those in McDonald *et al.* (1990). Where appropriate, sources other than McDonald *et al.* have been given. Ollier (1984) provides additional relevant definitions. In doing this, we point out that this handbook is not a textbook. We assume that users are either familiar with most of the terms we use here, or that they have access to appropriate textbooks.

Attribute definitions are presented in the same order as they appear on the entry screens in RTMAP. However, unlike Chapter 3, not all attributes are considered here. We consider only those that we feel need definitions as we use them in RTMAP.

4.1 SOILS DEFINITIONS

In RTMAP, soil refers to the organically affected upper part of the regolith. Soils are formed by interactions between the mineral material of the regolith and organic matter derived largely from vegetation growing in the regolith. Here we refer to 3 classifications that are used in Australia.

4.1.1 Principle Profile Form

The principle profile form comes from Northcote (1979). The simple definitions given here will allow people without any knowledge of soil science to place soils in one of the groups listed in the soils table. The definitions are taken largely from Northcote (1979), and readers should refer to that publication for more details. Northcote's classification refers to the arrangement of horizons in the soil.

O *Organic*

Organic soils are dominated by plant remains in at least the top 30 cm, and they can be much deeper. Any soil containing more than 30% organic matter may be considered to be organic.

Uc *Uniform, coarse textured*

Uniform soils are dominated by mineral material, and have small, if any, differences in grain size (texture) throughout the profile. The range of texture falls within the span of one texture group (see texture classes in Northcote, 1979). Uc soils have textures in the sand and sandy loam or coarser classes.

Um *Uniform, medium textured*

Uniform soils with textures in the loams and clay loams classes.

Uf *Uniform, fine textured, not cracking*

Uniform soils with textures in the clay classes, and seasonal cracking of the soil material does not occur.

Ug *Uniform, fine textured, cracking*

Uniform soils with textures in the clay classes, and the soil material is characterised by seasonal cracking.

Gc *Gradational, calcareous throughout*

Gradational soils are dominated by the mineral fraction and show increasingly finer (more clayey) texture grades on passing to greater depths. The changes in texture are gradual, and over the whole profile span more than one texture group. Gc soils are calcareous throughout.

Gn *Gradational, not calcareous throughout*

Gn soils are gradational, but are not calcareous throughout. However, calcium carbonate may be present in the lower parts of the soil, either as nodules or dispersed through the soil material.

Dr *Duplex, red clay B horizons*

Duplex soils are dominated by the mineral fraction and have a texture contrast of more than 1.5 texture groups between the A (surface) and B (subsurface) horizons. Further, the boundary between the two horizons is less than 10 cm thick. Dr soils have red B horizons, which in the Munsell Notation means a hue as red, or redder than, 5YR.

Db *Duplex, brown clay B horizons*

Db soils are duplex, with brown B horizons, which in the Munsell Notation means a hue yellower than 5YR.

Dy *Duplex, yellow–grey clay B horizons*

Dy soils are duplex, with yellow–grey B horizons.

Dd *Duplex, dark clay B horizons*

Dd soils are duplex, with dark B horizons, which in the Munsell Notation means a value/chroma less than 3/2 or 2/2.

Dg *Duplex, gley clay B horizons*

Dg soils are duplex, with gley B horizons, which in the Munsell Notation means any value on the Munsell 'gley' chart.

4.1.2 Great Soil Group

Stace *et al.* (1968) give a description and classification of Australian soils into great soil groups based on both soil morphology and soil genesis. Interested readers are referred to that publication. The great soil groups are listed here, with codes taken from Isbell and McDonald (1990).

SK	Solonchak
A	Alluvial soil
L	Lithosol
KS	Calcareous sand
DL	Desert loam
RBH	Red and brown hardpan soil
GC	Grey clay
BC	Brown clay
RC	Red clay
BE	Black earth
R	Rendzina
CM	Chernozem
PS	Prairie soil
W	Wiesenboden
SZ	Solonetz
SDS	Solodized solonetz
SC	Solodic soil
SH	Soloth
SB	Solonized brown soil
RBE	Red brown earth
NKB	Non calcic brown soil
C	Chocolate soil
BRE	Brown earth
KRE	Calcareous red earth
RE	Red earth
SS	Siliceous sand
ES	Earthy sand
GBK	Grey brown calcareous soil
RK	Red calcareous soil
GE	Grey earth
YE	Yellow earth
TR	Terra rossa soil
E	Euchrozem
X	Xanthozem
K	Krasnozem
GBP	Grey brown podzolic soil
RP	Red podzolic soil
YP	Yellow podzolic soil
BP	Brown podzolic soil
LP	Lateritic podzolic soil
GP	Gleyed podzolic soil
P	Podzol
HP	Humus podzol
PP	Peaty podzol
AH	Alpine humus soil
HG	Humic gley
NP	Neutral peat
ALP	Alkaline peat
ACP	Acid peat
NSG	No suitable group

4.1.3 New Australian Classification

A classification committee has recently produced a first approximation of a new scheme for the classification of Australian soils, based on morphological, chemical and physical properties (Isbell 1989). The following classes are used:

AN	Anthroposols
CA	Calcarosols
CH	Chromosols
FE	Ferrosols
HY	Hydrosols
KA	Kandosols
KU	Kurosols
ME	Melanosols
OR	Organosols
PO	Podosols
RU	Rudosols
SO	Sodosols
TE	Tenosols
VE	Vertosols

4.2 Landform Definitions

Landforms are an expression of the evolution of the landscape in which they occur. They are a culmination of processes, both past and present, acting on that landscape. Landforms are also highly visible in the landscape, and can be recognised from topographic maps and from various kinds of imagery, both airborne and spaceborne.

The landform units listed here are equivalent to the landform patterns of Speight (1990). According to Speight landform patterns are areas more than 600 m across, and are made up of landform elements. In RTMAP we use the concept of landform units and landform elements in much the same way. At a scale of 1:250 000 we are mapping landform units, and the landform elements are too small to map.

The listing is grouped together into related landform types under general headings, to give a hierarchical classification (see Chapter 3). Most of the landform units listed in this table are defined by Speight. Other definitions are either from the BMR Regolith Group, or from sources noted.

4.2.1 Landform Units

AL00 *Alluvial Landforms*

Complex landform pattern on valley floors. This landform pattern has active, inactive or relict erosion and aggradation by channelled and over–bank stream flow.

AL10 *Alluvial plain*

Level landform pattern with extremely low relief. The shallow to deep alluvial stream channels are sparse to widely spaced, forming a unidirectional integrated network. There may be frequently active erosion and aggradation by channelled and over–bank stream flow, or the landforms may be relict from these processes.

AL11 *Flood plain*•

Alluvial plain characterised by frequently active erosion and aggradation by channelled or over–bank stream flow. Unless otherwise specified, "frequently active" is to mean that flow has an Average Recurrence Interval of 50 years or less.

AL12 *Anastomotic plain*

Flood plain with slowly migrating deep alluvial channels, usually moderately spaced, forming a divergent to unidirectional integrated reticulated network. There is frequently active aggradation by over bank and channelled stream flow.

AL13 *Bar plain*

Flood plain with numerous rapidly migrating shallow alluvial channels forming a unidirectional integrated reticulated network. There is frequently active aggradation and erosion by channelled stream flow.

AL14 *Covered plain*

Flood plain with slowly migrating deep alluvial channels, usually widely spaced and forming a unidirectional integrated non–tributary network. There is frequently active aggradation by over–bank stream flow.

AL15 *Meander plain*

Flood plain with widely spaced, rapidly migrating, moderately deep alluvial stream channels which form a unidirectional integrated non–tributary network. There is frequently active aggradation and erosion by channelled stream flow with subordinate aggradation by over–bank stream flow.

AL20 *Alluvial terrace*

Former flood plain on which erosion and aggradation by channelled and over–bank stream flow is slightly active or inactive because of deepening or enlargement of the stream channel has lowered the level of flooding. A pattern that includes a significant active flood plain, or former flood plains at more than one level, becomes terraced land.

AL30 *Stagnant alluvial plain*

Alluvial plain on which erosion and aggradation by channelled and over–bank stream flow is slightly active or inactive because of reduced water supply, without apparent incision or channel enlargement that would lower the level of stream action.

AL40 *Terraced land*

Landform pattern including one or more terraces and often a flood plain. Relief is low or very low (9 – 90m). Terrace plains or terrace flats occur at stated heights above the top of the stream bank.

AL50 *Alluvial swamp*

Almost level, closed or almost closed depression with a seasonal or permanent water table at or above the surface, commonly aggraded by overbank stream flow and sometimes biological (peat) accumulation.

CO00 *Coastal lands*

Level to gently undulating landform pattern of extremely low relief eroded or aggraded by waves, tides, overbank or channel flow, or wind. The landform pattern may be either active or relict.

CO01 *Beach ridge plain*

Level to gently undulating landform pattern of extremely low relief on which stream channels are absent or very rare; it consists of relict parallel linear ridges built up by waves and modified by wind.

CO02 *Chenier plain*

Level to gently undulating landform pattern of extremely low relief on which stream channels are very rare. The pattern consists of relict, parallel linear ridges built by waves, separated by and built over flats aggraded by tides or over bank stream flow.

CO03 *Coral reef*

Continuously active or relict landform pattern built up to the sea–level of the present day or of a former time by corals and other organisms. It is mainly level, with moderately inclined to precipitous slopes below sea level. Stream channels are generally absent, but there may occasionally be fixed deep erosional tidal stream channels forming a disintegrated non–tributary pattern.

CO04 *Marine plain*

Plain eroded or aggraded by waves, tides, or submarine currents, and aggraded by deposition of material from suspension and solution in sea water, elevated above sea level by earth movements or eustacy, and little modified by subaerial agents such as stream flow or wind.

CO05 *Tidal flat*

Level landform pattern with extremely low relief and slowly migrating deep alluvial stream channels which form dendritic tributary patterns; it is aggraded by frequently active tides.

CO06 *Coastal dunes*

Level to rolling landform pattern of very low to extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind. This landform pattern occurs in usually restricted coastal locations.

DE00 *Delta*

Flood plain projecting into a sea or lake, with slowly migrating deep alluvial channels, usually moderately spaced, typically forming a divergent distributary network. This landform is aggraded by frequently active over–bank and channelled stream flow that is modified by tides.

DU00 *Dune field*

Level to rolling landform pattern of very low to extremely low relief without stream channels, built up or locally excavated, eroded or aggraded by wind.

DU01 *Longitudinal Dune field*

Dune field characterised by long narrow sand dunes and wide flat swales. The dunes are oriented parallel with the direction of the prevailing wind, and in cross section one slope is typically steeper than the other.

ER00 *Erosional landforms*

Landform pattern of very low to high relief and very gentle to steep slopes. The pattern is eroded by continuously active to slightly active or inactive geomorphic processes.

ER10 *Erosional plain*

Level to undulating or, rarely, rolling landform pattern of extremely low relief (< 9 m) eroded by continuously active to slightly active or inactive geomorphic processes.

ER11 *Pediment*

Gently inclined to level (< 1% slope) landform pattern of extremely low relief, typically with numerous rapidly migrating, very shallow incipient stream channels which form a centrifugal to diverging integrated reticulated pattern. It is eroded, and locally aggraded, by frequently active channelled stream flow or sheet flow, with subordinate wind erosion. Pediments characteristically lie down–slope from adjacent hills with markedly steeper slopes.

ER12 *Pediplain*

Level to very gently inclined landform pattern with extremely low relief and no stream channels, eroded by slightly active sheet flow and wind. Largely relict from more effective erosion by stream flow in incipient channels. Formed from coalescing pediments.

ER13 *Peneplain*

Level to gently undulating landform pattern with extremely low relief and sparse slowly migrating alluvial stream channels which form a non–directional integrated tributary pattern. It is eroded by slightly active sheet flow, creep, and channelled and over bank stream flow.

ER14 *Etchplain*

Level to undulating or, rarely, rolling landform pattern of extremely low relief, formed by deep weathering and then erosional removal of the resulting weathered regolith. Removal of the weathered material may be either partial or complete (see also Ollier 1984).

ER20 *Rises*

Landform pattern of very low relief (9 – 30 m) and very gentle to steep slopes. The fixed erosional stream channels are closely to very widely spaced and form a dendritic to convergent, integrated or interrupted tributary pattern. The pattern is eroded by continuously active to slightly active creep and sheet flow.

ER30 *Low hills*

Landform pattern of low relief (30 – 90 m) and gentle to very steep slopes, typically with fixed erosional stream channels, closely to very widely spaced, which form a dendritic or convergent integrated tributary pattern. There is continuously active sheet flow, creep, and channelled stream flow.

ER40 *Hills*

Landform pattern of high relief (90 – 300 m) with gently sloping to precipitous slopes. Fixed, shallow erosional stream channels, closely to very widely spaced, form a dendritic or convergent integrated tributary network. There is continuously active erosion by wash and creep and, in some cases, rarely active erosion by landslides.

ER50 *Mountains*

Landform pattern of very high relief (> 300 m) with moderate to precipitous slopes and fixed erosional stream channels which are closely to very widely spaced and form an integrated tributary network. There is continuously active erosion by collapse, landslide, sheet flow, creep, and channelled stream flow. Mountains usually stand above the surrounding landscape.

ER60 *Escarpment*

Steep to precipitous landform pattern forming a linearly extensive, straight or sinuous inclined surface which separates terrains at different altitudes, that above the escarpment commonly being a plateau. Relief within the landform pattern may be high (hilly) or low (planar). The upper margin is often marked by an included cliff or scarp.

ER70 *Badlands*

Landform pattern of low to extremely low relief (< 90 m) and steep to precipitous slopes, typically with numerous fixed erosional stream channels which form a dendritic to parallel integrated tributary network. There is continuously active erosion by collapse, landslide, sheetflow, creep and channelled stream flow.

ER80 *Drainage depression*

Depression cut into a surface by erosional processes. This term should be used only in cases where a single depression or valley is incised into a plateau or other surface, and where the scale of mapping does not allow the depression to be subdivided into its component parts (e.g. rises, flood plain).

FA00 *Fan*

Level (> 1% slope) to moderately inclined complex landform pattern of extremely low relief with a generally fan–shaped plan form. The channels form a centrifugal to divergent, integrated, reticulated to distributary pattern.

FA01 *Alluvial fan*

Level (> 1% slope) to very gently inclined complex landform pattern of extremely low relief with a generally fan–shaped plan form. The rapidly migrating alluvial stream channels are shallow to moderately deep, locally numerous, but elsewhere widely spaced. The channels form a centrifugal to divergent, integrated, reticulated to distributary pattern. The landform pattern includes areas that are bar plains, being aggraded or eroded by frequently active channelled stream flow, and other areas comprising terraces or stagnant alluvial plains with slopes that are greater than usual, formed by channelled stream flow but now relict. Incision in the up–slope area may give rise to an erosional stream bed between scarps.

FA02 *Colluvial fan/footslope*

Very gently to moderately inclined complex landform pattern of extremely low relief with a generally fan–shaped plan form. Divergent stream channels are commonly present, but the dominant process is colluvial deposition of materials. The pattern is usually steeper than an alluvial fan.

FA03 *Sheet–flood fan*

Level (< 1% slope) to very gently inclined landform pattern of extremely low relief with numerous rapidly migrating very shallow incipient stream channels forming a divergent to unidirectional, integrated or interrupted reticulated pattern. The landform pattern is aggraded by frequently active sheet flow and channelled stream flow, with subordinate wind erosion.

KA00 *Karst*

Landform pattern of unspecified relief and slope (for specification use terms such as "Karst rolling hills") typically with fixed deep erosional stream channels forming a non–directional disintegrated tributary pattern and many closed depressions without stream channels. It is eroded by continuously active solution and rarely active collapse, the products being removed through underground channels.

MA00 *Made land*

Landform pattern typically of very low or extremely low relief and with slopes in the classes level and very steep. Sparse, fixed deep artificial steam channels form a non–directional interrupted tributary pattern. The landform pattern is eroded and aggraded, and locally built up or excavated, by rarely active human agency.

ME00 *Meteor crater*

Rare landform pattern comprising a circular closed depression with a raised margin, it is typically of low to high relief and has a large range of slope values, without stream channels, or with a peripheral integrated pattern of centrifugal tributary streams. The pattern is excavated, heaved up and built up by a meteor impact and now relict.

PL00 *Plain*

Level to undulating or, rarely, rolling landform pattern of extremely low relief (< 9 m). Some types of plains are described under alluvial landforms, and some are also described under erosional landforms (see ER10, p71).

PL01 *Depositional plain*

Level landform pattern with extremely low relief formed by unspecified depositional processes.

PL02 *Lacustrine plain*

Level landform pattern with extremely low relief formerly occupied by a lake but now partly or completely dry. It is relict after aggradation by waves and by deposition of material from suspension and solution in standing water. The landform pattern is usually bounded by wave-formed cliffs, rock platforms, beaches, berms and lunettes that may be included or excluded.

PL03 *Playa plain*

Level landform pattern with extremely low relief, typically without stream channels, aggraded by rarely active sheet flow and modified by wind, waves, and soil phenomena. Playa plains are sediment sinks and are the lowest parts of the landscape.

PL04 *Sand plain*

Level landform pattern with extremely low relief, typically without stream channels, aggraded by active wind deposition and rarely active sheet flow.

PT00 *Plateau*

Level to rolling landform pattern of plains, rises or low hills standing above a cliff, scarp or escarpment that extends around a large part of its perimeter. A bounding scarp or cliff may be included or excluded; a bounding escarpment would be an adjacent landform pattern.

VO00 *Volcano*

Typically very high and very steep landform pattern without stream channels, or with erosional stream channels forming a centrifugal or radial tributary pattern. The landform is built up by volcanism, and modified by erosional agents.

VO01 *Caldera*

Rare landform pattern typically of very high relief and steep to precipitous slopes. It is without stream channels or has fixed erosional channels forming a centripetal integrated tributary pattern. The landform has subsided or was excavated as a result of volcanism.

VO02 *Volcanic cone*

Typically low to high relief and very steep landform pattern without stream channels, or with erosional rills forming a radial tributary pattern. The landform is built up by volcanism, and slightly modified by erosional agents.

VO03 *Lava plain*

Level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed stream channels which form a non-directional integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (lava flow) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow.

VO04 *Ash plain*

Level to undulating landform pattern of very low to extremely low relief typically with widely spaced fixed stream channels which form an integrated or interrupted tributary pattern. The landform pattern is aggraded by volcanism (ash fall) that is generally relict; it is subject to erosion by continuously active sheet flow, creep, and channelled stream flow.

4.2.2 Structural Control

The type of structural control on landforms in the landform unit can often be determined from aerial photographs or satellite imagery. There is commonly a strong relationship between drainage patterns and structure. Hillslope form also reflects rock structure in many cases.

NS *No structural control*

Dendritic drainage patterns with no preferred orientation, and generally smooth slope forms often indicate homogeneous rocks which exercise no control on landforms.

AD *Anti dip slope*

Anti dip slopes, also known as scarp slopes or scarps, are formed across the dip of bedded rocks. They are frequently irregular because of differential erosion of more and less resistant rocks that are interbedded.

AN *Anticline*

Anticlines are characterised by outward facing dip slopes and inward facing anti–dip slopes. They also may have divergent drainage patterns. In the extreme form, domes, drainage may be radial.

BF *Block faulting*

Individual blocks may be either up– or down–thrown to give distinctive features in the landscape.

CU *Cuesta forms*

Cuestas have a steep anti dip slope and a more gentle dip slope. Both strike and dip of the underlying rock are reflected in the landforms.

DB *Dipping beds*

In areas where bedded rocks dip at significant angles, differential erosion of more and less resistant rocks can lead to linear valleys and ridges.

DI *Dip slope*

In some cases a long very gentle dip slope gives rise to a gently slope ramp. Parallel drainage is often found on such structural ramps.

DS *Dyke/sill*

Dykes and sills are frequently exposed by differential removal, by erosion, of the softer rocks around them. The volcanic rock then stands out in the landscape.

FT *Faulted*

Faults may show up as lineaments in the landscape, and in some cases may show up as a scarp. A fault scarp is a scarp formed by faulting, whereas a fault line scarp is one formed by erosion and backward retreat of a fault scarp.

HO *Horizontal bedding*

Horizontally bedded rocks are representedby flat surfaces and a series of benches and cliffs.

HG *Horst/graben*

Horsts and grabens are formed by widespread block faulting giving rise to a mountain and valley topography that owes its origin in part at least to regional block faulting.

JN *Jointing*

Jointing patterns are usually expressed in the landscape as a result of weathering and geomorphic processes taking advantage of the weak points provided by the joints. Commonly the drainage pattern reflects such joint control.

MN *Monocline*

Monoclines may show a fall from a high to a low level in the landscape.

SA *Strike aligned*

In many areas both ridges and rivers are aligned along the strike of the bedrock. This may lead to the exposure of a series of cuestas, or in some cases anticlines and synclines.

SN *Syncline*

Synclines are characterised by inward facing dip slopes and outward facing anti dip slopes. Drainage may be convergent.

4.3 ENVIRONMENTAL HAZARD DEFINITIONS

Evidence of environmental hazards can be observed in the field, and assessments of hazard liability can be made. The hazards listed here are those that are either directly related to the regolith and landforms (e.g. landslides), or their impacts are restricted to particular landscape types that are identified as part of a regolith terrain map (e.g. floods). Readers who want more information about environmental hazards should, as a beginning point, refer to Heathcote and Thom (1979) or Blong and Johnson (1986).

AV *Snow avalanche*

Rapid movement of snow down mountain slopes.

CO *Coastal erosion*

Erosion of coastal land by waves and wind. This may be brought about by several factors including human disturbance of the foredune, and various effects of climatic change such as rising sea level, and increased storminess.

CP *Coastal progradation*

Accumulation of sediment along a coast, causing the coast to advance seawards. This may destroy vegetation belts, such as mangroves, and isolate man-made structures from the sea.

FF *Flash flood*

Rapid rise of water level in rivers, sometimes with overbank flow, resulting from high intensity rain storms. These events are common in lower rainfall areas, and may occur downstream of the location of rainfall.

FL *Flood*

Rise of water in rivers followed by overbank flow, resulting from prolonged heavy rainfall. Flood waters may affect areas outside the area of rainfall.

LA *Landslide*

Rapid mass movement of regolith material down hillslopes.

RO *Rockfall*

Fall of rock from vertical or near vertical cliffs.

SA *Salinity*

Accumulation of salts at the surface or within the near–surface soil. This can arise from a number of causes ranging from a rise in water table levels in irrigated areas to emergence of subsurface water in lower footslope areas.

SC *Solution cavities*

In some circumstances, particularly on calcareous rock types, solution processes within the underlying rock can lead to the development of hollows and possibly collapse.

SD *Sand drift*

Movement of sand by wind erosion, transport and deposition.

SO *Soil erosion*

Loss of soil by erosion processes, including surface wash and rill erosion, as well as wind erosion.

ST *Storm surge*

Unusually high temporary sea levels resulting from storms that force sea water on to the land through a combination of strong onshore winds, high tides, and lowered barometric pressure.

SU *Subsidence*

Sinking of the ground surface, either slowly or by more rapid collapse, due, for example, underground caves in limestone, mines, and removal of water from subsurface aquafers.

TS *Tsunami*

Ocean waves generated by either volcanic or seismic activity, usually on the sea floor. Tsunami are sometimes erroneously called tidal waves.

VE *Volcanic activity*

Effects resulting from volcanic eruption.

4.4 DRAINAGE DEFINITIONS

4.4.1 Drainage Pattern

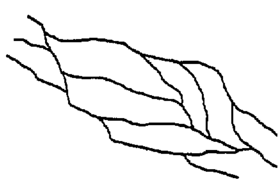
Drainage pattern refers to the plan shapes made by drainage channels on the land surface. It should not be confused with *channel pattern*, which refers to the plan shape of river reaches. Drainage patterns reflect a number of elements in the landscape. They may reflect underlying rock structures, or the nature of the original surface on which they were developed. Some of these interpretations are discussed briefly in the relevant definitions below.

Simple rivers have a dendritic pattern. Complications to a dendritic pattern mean that the drainage has been affected by rock structure or events in its geomorphic history or both. Proper interpretation of drainage patterns contributes to an understanding of the geomorphic history of an area, and so to an understanding of regolith development. Drainage patterns are often one of the oldest features in a landscape, because they are developed very soon after an area is exposed to surface activity, and they can persist through several tectonic and erosional episodes.

The drainage patterns listed here are derived from a number of sources, including Ollier (1981) and Speight (1990).

AB *Anabranching*

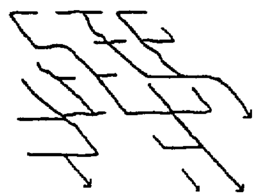
A drainage pattern where the channels divide and then join further down stream. This pattern is sometimes referred to as anastomosing, or reticulated. It is similar in form to the arrangement of channels in a



braided river channel, but is at a much larger scale.

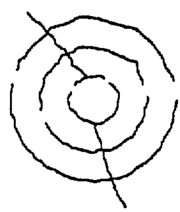
AG *Angulate*

Channels follow a roughly rhomboid plan. This type of pattern occurs mainly where the underlying rock is weakened by intersecting joints. These joints control the location of drainage lines.



AN *Annular*

A drainage pattern where channels form parts of circles. Annular patterns are usually controlled by domal or anticlinal rock structures which are picked out by channels. They may be either circular or elliptical.

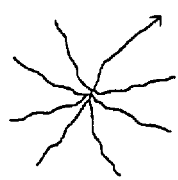


BA *Barbed*

Barbed drainage patterns are those where tributaries join the main channel at angles of greater than 90^{o}. In this situation the tributaries tend to flow in a direction opposite that of the main channel. This can mean that the flow direction of the main channel has been reversed.

CP *Centripetal*

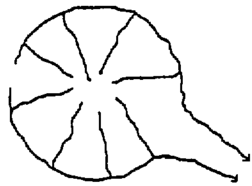
A drainage pattern where channels flow in towards a central point or area from a surrounding area encompassing at least 180^{o}. In many cases this



central area is a closed depression, such as a caldera, in which case the incoming channels drain a surrounding area encompassing 360^{o}.

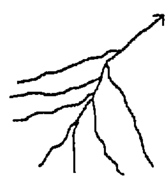
CR *Circumvolcanic*

In many areas with volcanic landforms, drainage lines flow in semicircular courses around volcanoes. These drainage lines are called circumvolcanic. Generally they indicate that former drainage lines have been diverted into a circular course by the eruption and growth of the volcano.



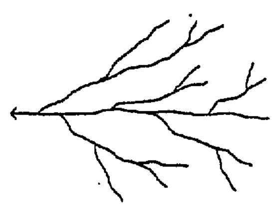
CV *Convergent*

A drainage pattern where channels converge towards a point or area from a surrounding area encompassing less than 180^{o}. Such patterns can be found, for example, on synclines.



DN *Dendritic*

Integrated drainage patterns where small branch channels join, usually at acute angles, to feed a trunk channel. They show no preferred orientation, and are typical of areas where the underlying rock is more or less homogeneous.

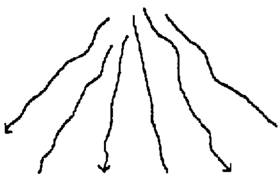


DS *Distributary*

A drainage pattern where a single channel breaks or diverges into a number of smaller channels. This pattern is typical of deltas, but can occur in any area where a single channel flows out of a confining valley. In some parts of Australia these areas are called "floodouts".

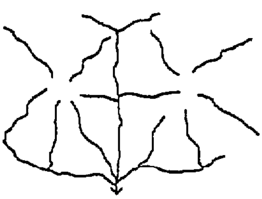
DV *Divergent*

A drainage pattern where multiple channels diverge from a small area to a surrounding area. Such patterns can be found, for example, on the ends of anticlines, and are typical of fans.



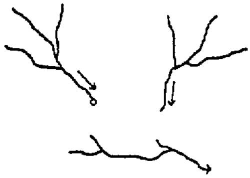
GU *Gutter*

Gutter drainage, like circumvolcanic drainage, is associated with volcanoes. It occurs where two volcanoes overlap, and the drainage lines flow along the low line of intersection.



IN *Interrupted*

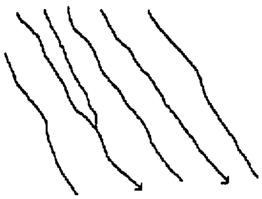
Drainage where the channel segments are short and unconnected. Typically this occurs in karst landforms, and in areas where the drainage pattern has not been fully



integrated. Some parts of the arid centre of Australia show this pattern, because of the lack of sufficient precipitation, and disruption of drainage lines by wind blown materials.

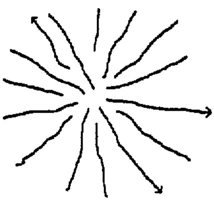
PA *Parallel*

A drainage pattern where the channels are parallel to each other. This type of drainage is commonly initiated on sloping surfaces, and the presence of a parallel drainage pattern or its remnants may suggest the former presence of such a surface.



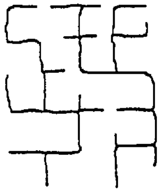
RA *Radial*

A drainage pattern where the channels radiate from a point or small area. Commonly this occurs on volcanoes or domal structures. A radial drainage pattern infers the former presence of such features, even if they are no longer present in the landscape.



RC *Rectangular*

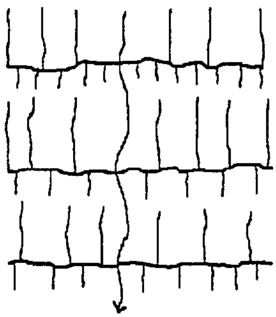
A drainage pattern in which the channels follow a roughly rectangular plan with channels joining at about 90^{o}. This type of pattern occurs where the underlying rock is broken by rectangular jointing or, less frequently, bedding which



controls stream direction one way and joints the other.

TR *Trellis*

A drainage pattern where secondary channels flow at right angles to the main channel. The secondary channels are in turn joined at right angles by small tributaries flowing parallel to the main channel. This pattern is common in well bedded rocks, commonly with scarp and dip slopes. Small tributaries on the scarp slopes are short and steep, while those on the dip slopes are longer and more gently sloping.



4.4.2 Drainage Character

Drainage character refers to the frequency of flow in river channels in the landform unit, and for RTMAP is restricted to the following:

D *Dry*

Channels which flow on very rare occasions. This drainage character is confined largely to the arid areas of central Australia.

I *Intermittent*

Channels which flow on a seasonal basis, containing water during wet parts of the year, and drying up during periods with no rain. Much of northern Australia has this drainage character.

P *Perennial*

Channels which flow all year round. This drainage character is confined to wetter areas on the margins of the Australian continent.

4.4.3 Drainage Type

Drainage type refers to the relationship between drainage lines and landscape evolution. Currently the following types are recognised.

A *Antecedent*

Antecedent drainage is developed when uplift or warping raises an area of highlands across the path of a river, but the uplift is sufficiently slow to allow river downcutting to keep pace, and therefore maintain its course.

C *Captured*

Drainage capture, or piracy, occurs when drainage from one catchment is diverted into another catchment. Sharp bends in river direction and barbed drainage patterns can indicate river capture. The stream from which drainage is captured is said to be beheaded.

D *Diverted*

Drainage may be diverted when uplift or warping raises an area of highlands across the path of a river. If the river cannot cut down its bed as fast as the rate of uplift, the river will be defeated, and then diverted to flow in another direction. In extreme cases, a closed depression with a lake may develop (e.g. Lake George, NSW).

N *Normal*

Normal drainage develops where there are no apparent tectonic, structural or lithologic controls on the major river/landscape relationships.

R *Reversed*

Reversed drainage is the reversal of flow in a river channel, and can occur as a result of tectonic tilting, causing lowering of the headwaters of a river system. Sometimes river capture can lead to drainage reversal.

S *Superimposed*

Superimposed drainage occurs when a river cuts down through rocks of varying hardness from above. Softer rocks are readily removed, but harder rocks remain as higher parts of the landscape. This commonly leads to rivers flowing in gorges right through high areas.

U *Underground*

Drainage occurring underground is found most commonly in karst areas. Surface drainage may disappear underground when it enters a limestone area, to emerge often many kilometres away.

4.4.4 Stream Channel Spacing

Stream channel spacing is a measure of drainage density, the total length of channel per unit area (Speight 1990). At a very broad level it is affected by precipitation, higher rainfall areas generally having closer stream channel spacing. At more local levels where climate is more uniform, stream channel spacing can reflect underlying lithology, with softer rocks often having a closer stream channel spacing than harder rocks.

Values for stream channel spacing can be obtained by laying a ruler on a map, and counting the number of channels that cross a line equivalent to 2 or 3 km. Several such measurements will give a representative value for each landform unit. Values for stream channel spacing are restricted to:

AB	Absent or very rare	>2500 m
SP	Sparse	1500 – 2500 m
VW	Very widely spaced	1000 – 1500 m

WS	Widely spaced	625 – 1000 m	
MS	Moderately spaced	400 – 625 m	
CS	Closely spaced	250 – 400 m	
VC	Very closely spaced	150 – 250 m	
NU	Numerous	< 150 m	

4.5 GEOMORPHIC PROCESS DEFINITIONS

In the database, geomorphic processes are those which form or modify landform units. They can refer to either present or past activity. This means that processes occurring now as well as those responsible for the evolution of a regolith terrain unit can be entered into the database. An active/relict (A/R) code is used to distinguish the two.

Brief definitions are included here. For more detailed descriptions of these processes the user is referred to a textbook on geomorphology, such as Chorley *et al.* (1984). Other suitable references are given at various points.

GR00 *Gravity*

Any geomorphic process that acts mainly as a result of gravity. For more details see Selby (1982).

GR01 *Vertical collapse*

Collapse of large fragments of rock and/or soil, commonly from cliff faces. The collapsed materials accumulate where they fall, and may be acted on by other processes.

GR02 *Particle fall*

Free fall of small particles of rock and/or soil from or near vertical faces.

GR03 *Creep*

Slow movement of rock and/or soil particles down slope under the influence of gravity. Creep operates at rates of a few millimetres per year, with wetting and drying, shrinking and swelling, and freezing and thawing all contributing to the down slope movement of material.

GR04 *Landslide*

Translational movement of material along a shearplane under the influence of gravity. The moving material may be either a single coherent mass, or it may consist of a number of sliding fragments. In this type of movement, the material generally maintains its orientation relative to the land surface. The resulting deposit contains unbroken blocks or rafts of material.

GR05 *Mudflow*

Turbulent movement of material down slope under the influence of gravity. In this type of movement the moving mass tumbles, rolls and flows down slope. The resulting deposit is a mixture of material of all sizes, with no obvious orientation or indication of original structure.

WT00 *Water*

The movement and deposition of material through the agency of water. For more details see Morisawa (1985).

WT01 *Channelled stream flow*

Erosion, transport and deposition of material in stream channels. These commonly give well sorted deposits which are confined to river channels, either modern or relict (channel deposits).

WT02 *Over–bank stream flow*

Erosion, transport and deposition of material on flood plains and other areas adjacent to rivers by water which has flowed out of a confined channel (over–bank deposits).

WT03 *Sheet flow, sheet wash, surface wash*

Erosion, transport and deposition of material by sheets of water flowing over the ground surface. This unconfined flow occurs on hill slopes and on low angle landform units. It commonly removes fine material, leaving coarser material behind as a lag deposit.

WT04 *Waves*

Erosion, transport and deposition of material by wave action either on the sea coast or along lake edges. For more details on coastal processes see Davies (1980).

WT05 *Tides*

Erosion, transport and deposition of material by movement of tidal currents.

WT06 *Detrital deposition in still water*

Deposition of detrital material from a body of standing water onto the floor of the basin. In terrestrial landscapes this occurs in lakes. Sources of detrital material include channel flow into the lake, and wave action along lake edges.

WT07 *Rill/gully erosion*

Linear erosion by water, producing steep sided channels. Rills are less than 0.3m deep and gullies are more than 0.3m deep.

WT08 *Subsurface solution/piping*

The movement of materials by subsurface water flow, both in solution and in suspension, to result in changes to the shape of the land surface. Such removal can lead to both circular and linear depressions. The latter are sometimes called percolines. Subsurface removal of weathered materials can lead to the development of tunnels, or pipes, which may collapse to form shafts. Such processes can occur in most regolith materials and rocks, and reaches its best development in limestone karst areas.

IC00 *Ice*

Erosion, transport and deposition of material by moving ice. For more details see Davies (1969).

IC01 *Frost*

Freezing and thawing of water, which leads to shattering and movement of rock fragments, and disturbance of soil material. Processes include solifluction, and the development of patterned ground.

IC02 *Glacial erosion*

Erosion and transport of material by glacial ice, giving rise to distinctive landforms such as U–shaped valleys and cirques.

IC03 *Glacial deposition*

Deposition of material from melting ice. The deposits are referred to by the general term moraine.

WI00 *Wind*

Erosion, transport and deposition of material by wind. For more details see Mabbutt (1977).

WI01 *Wind erosion (deflation)*

Erosion of material by the action of wind. This may involve entrainment of sand and dust particles, and their movement to other locations. It also includes the action of sand corrasion to produce ventifacts.

WI02 *Sand deposition (wind)*

Deposition of sand by wind to form various landform types including dunes and sand sheets.

WI03 *Dust deposition (wind)*

Deposition of dust being transported by wind in the atmosphere as suspended load. This process is responsible for deposition of loess. Where the dust is composed of clay pellets, it forms a special kind of loess, sometimes called parna in Australia.

DI00 *Diastrophism; earth movements*

Diastrophic movements are those which result directly or indirectly in relative or absolute changes of position, level or attitude of rocks forming the earth's crust. This includes uplift and faulting.

VO00 *Volcanism*

Volcanism refers to the group of processes generated by volcanic activity on the land surface (see Ollier 1988).

VO01 *Lava flow*

The flow of molten rock across the land surface.

VO02 *Ash flow*

The flow of volcanic ash material across the land surface. This includes nuée ardentes. The resulting deposits are sometimes called ignimbrites.

VO03 *Ash fall*

The fall of volcanic ash on to the land surface, typically leading to mantles of volcanic ash (tephra) over all parts of the landscape.

BI00 *Biological agents*

Formation or changes in the shape of landforms by animals or plants, for example, the development of coral reefs.

HU00 *Human agents*

Formation or changes in the shape of landforms by human activity.

MT00 *Meteor impact*

Formation or changes in the shape of landforms by meteorite impact, typically to produce craters.

4.6 WEATHERING PROCESS DEFINITIONS

Weathering is an essential first step in landscape development. Without weathering there can be no soil formation, nor can there be any erosion and transportation of rock materials. Weathering processes range from simple physical breaking of rocks into smaller pieces to complex chemical alteration of rock materials. Refer to Ollier (1984) for a detailed discussion of weathering and landforms.

WE00 *Weathering*

Weathering refers to any process which modifies rocks, either physically by reducing the size of fragments, or chemically by altering the composition of constituent rock materials.

PH00 *Physical weathering*

Physical weathering is any process which leads to a reduction in the size of rock fragments.

PH01 *Abrasion*

Abrasion is the mechanical breaking of rocks or minerals by either friction or impact. Friction is common at the base of glaciers, for example, whereas impact abrasion is more common in streams and in areas of wind transport.

PH02 *Frost weathering*

Breaking and separation of rock fragments by the force exerted when water freezes to ice. Freeze–thaw cycles are very important in the breakdown and mixing of rock and soil material.

PH03 *Induced fracture*

Induced fracture occurs when a large rock rests on an underlying rock. This sets up stresses which can act on both the underlying and overlying rock.

PH04 *Insolation weathering*

Insolation weathering occurs when temperature changes cause expansion and/or shrinkage of rocks. Repeated temperature changes may cause rocks to fracture, and for insolation weathering the heating agent is the sun.

PH05 *Moisture swelling*

Considerable changes in rock volume can be caused by a reversible absorption of moisture, and the volume changes may be enough to cause physical weathering.

PH06 *Sheeting*

Sheeting is the division of rock into sheets by joint–like fractures that are generally parallel to the ground surface. It is caused by pressure release and expansion of rock masses following erosion. Topographic jointing is another name for this process.

PH07 *Salt weathering*

The growth of salt crystals from solution can sometimes cause breakdown of rock materials in a manner similar to that caused by freezing of water.

PH08 *Volume increase*

Chemical alteration of rocks and minerals may cause an increase in volume. This volume increase usually leads to exfoliation, the peeling of thin shells of material from the parent rock.

PH09 *Wetting and drying*

Repeated wetting and drying of rock materials can lead to physical beak down of the materials into smaller fragments.

CH00 *Chemical weathering*

Chemical weathering occurs with any chemical alteration of rocks or minerals. It results from chemical reactions of minerals with air and water.

CH01 *Solution*

Solution is usually the first stage of chemical weathering, and may take place in running water or in a thin film of water round a solid particle. Dissolved chemicals are removed from the weathering rock.

CH02 *Oxidation and reduction*

Oxidation is a reaction between minerals and oxygen to produce oxides or, with water, hydroxides. Reduction is the opposite of oxidation and usually takes place in waterlogged and other anaerobic sites. Alternating oxidation and reduction in, for example, a zone of fluctuating water level, often leads to mottling of weathered materials.

CH03 *Carbonation*

Carbonation is the reaction of carbonate or bicarbonate ions with minerals. Carbon dioxide is common in soil air, and carbonation can be quite rapid where carbonic acid is readily available.

CH04 *Hydration*

Hydration is the addition of water to a mineral to form hydrated mineral forms, or hydroxides. Hydration is an important process in clay mineral formation.

CH05 *Chelation*

Chelation, or complexing, is the holding of an ion, usually a metal, within a ring structure of organic origin. It is an important process involving both mineral and organic materials.

CH06 *Hydrolysis*

Hydrolysis, a very important chemical weathering process, is a chemical reaction between minerals and the H^+ and OH^- ions of water.

CH07 *Ferrolysis*

Replacement of Ca, K, Na ions with Fe ions. The former are then lost to the soil water or ground water.

CH08 *Chemical precipitation/evaporation*

In suitable chemical environments various chemicals precipitate from solution and are deposited in various parts of the landscape. This may be an important source of materials in some parts of the landscape, especially in situations where water comes to the surface and is then evaporated.

IN00 *Induration*

Induration processes lead to either absolute or relative accumulation of a cementing agent, to form a duricrust. Sometimes the cementing agent replaces regolith materials. A duricrust is a hard crust formed by weathering processes.

IN01 *Bauxitic induration*

Cementing largely by aluminous materials.

IN02 *Calcareous induration*

The *in situ* cementation and/or replacement of regolith by carbonate.

IN03 *Clay induration*

Induration of regolith by clay materials.

IN04 *Ferruginous Induration*

Cementing by iron to form ferricrete, sometimes referred to as lateritic duricrust.

IN05 *Gypsiferous induration*

The *in situ* cementation and/or replacement of regolith by gypsum.

IN06 *Siliceous induration*

The *in situ* cementation and/or replacement of regolith by silica.

HA00 *Hydrothermal alteration*

Hydrothermal alteration is produced by chemical changes in rock materials caused by hot water and steam rising through country rock. This is not weathering, but produces very similar effects. The best field distinction between clay bodies formed by weathering and hydrothermal alteration is that weathering decreases with depth, and hydrothermal alteration increases with depth.

BI00 *Biotic weathering*

Biotic weathering is a combination of chemical and physical weathering brought about by biological agents. It has a wide variety of effects, but is not usually more than locally important. See Ollier (1984) for more details.

4.7 REGOLITH DEFINITIONS

Landform classification has reached the stage where, although there may be minor disagreements, most people generally agree on the major groupings. However, regolith classification is an entirely different matter. There is still disagreement about what regolith is, and this disagreement extends to the use of different terms to describe regolith types. A good example is the use of the words *laterite* and *ferricrete.*

In developing a classification of regolith we must keep in mind its purpose. We are mapping RTUs at a publication scale of 1:250,000, although field mapping will be at 1:100,000. This rules out, in most cases, mapping specific regolith materials such as the mottled zone of a laterite profile. RTUs will contain groupings of specific regolith materials. Often these groupings will be related both spatially and genetically, in the same way as the soils in a toposequence are related. The difference between a regolith toposequence and a soil toposequence is that the former is likely to be deeper and more complex. A group of regolith types will be a three dimensional entity which frequently contains a wide variety of specific materials.

4.7.1 Regolith Type

The list presented here contains the basic regolith types, derived in part from Speight and Isbell (1990). It will expand, particularly with the addition of categories of regolith profiles, as data come both from our field mapping program and from workers outside the BMR.

WMU00 *Weathered material (origin unknown)*

This category covers those materials that are weathered, and so are regolith, but contain no features that allow them to be characterised as being either in situ or transported.

WIR00 In situ *weathered rocks*

Rock masses that have suffered chemical, mineral and physical changes on exposure to land surface processes, resulting in a loss of up to 85% of the rock strength (Speight and Isbell 1990). Weathered rocks have thus been altered by weathering processes such that they are broken into smaller fragments and/or changed in composition. The degree of weathering can vary from slight to complete (see under Degree of Weathering).

WIR10 *Deep weathered regolith*

Deep (> 2 m) *in situ* regolith produced by weathering of rock masses due to exposure to land surface processes. A number of terms are in general use for naming all or parts of a weathering profile. Some definitions are given here, with preferred terms for use in RTMAP indicated. An undisturbed deep weathering profile consists of an upper soil layer and a lower *in situ* weathered layer. The former is developed from the material below, but may have been disturbed. It is best classed as residual material. The latter is quite undisturbed.

The various layers or zones in deep weathered regolith are often assumed to be genetically related. In some cases this may be true, but there are so many exceptions reported in the literature that we have chosen to leave out all genetic connotations in our definitions. Moreover, the various layers do not always occur in the same sequence, making genetic implications suspect in many cases.

The term *lateritic profile* is sometimes used to refer to a particular type of deep weathered regolith which has ferruginous upper layers, and kaolinised lower layers.

WIR11 *Saprolite*

The term *saprolite* (Becker 1895) is used in RTMAP to refer to all those parts of a weathering profile which have been formed strictly *in situ*, with interstitial grain relationships being undisturbed. This contrasts with residual material, which has been disturbed (see below, WIR20). Saprolite is altered from the original rock by mainly chemical alteration and loss without any change in volume. This is sometimes referred to as constant volume alteration. Saprolite is often equivelent to the C horizon in pedology. Some workers confine the use of the term to weathered material below the zone of pedological alteration (or pedoplasmation – Flach *et al* 1968).

WIR12 *Structured saprolite*

Saprolite which still contains rock structure, and in which only a relatively small proportion of the weatherable minerals in the original rock have been altered. This material is called saprock by some workers.

WIR13 *Mottled zone*

Material, usually strongly weathered, where iron segregation results in the development of ferrugenous mottles, commonly reddish in colour. Size of mottles can range from millimetres to tens of centimetres. The latter are sometimes called mega mottles. The mottled zone is frequently near the top of a deeply weathered regolith profile, lying above the pallid zone.

WIR14 *Pallid zone*

Kaolinised zone usually found in the lower part of a weathering profile. This zone is generally light grey to white in colour, and may or may not retain original rock structure.

WIR20 *Residual material*

Material derived from weathering of rock and remaining in place after part of the weathered material has been removed. It results from loss of volume from the weathered mass.

WIR21 *Lag*

A deposit, commonly thin, of fragments larger than sand size, spread over the land surface. Its most common origin is as the coarse material left behind after fine material has been transported away by wind or, less commonly, sheet flow.

WIR22 *Residual sand*

A deposit of sand sized material, commonly composed largely of quartz, covering the land surface, and derived from the removal of finer material either in solution or suspension in subsurface water. It includes the sandy top of some soil types.

WIR23 *Residual clay*

Clay material that remains behind after weathering has removed part of the original rock. A common example is the clay soil material found on limestone after solution has removed the calcareous part of the rock.

WIR24 *Soil on fresh bedrock*

In some areas, particularly on steep slopes, or on young surfaces, the regolith consists of soil material up to 2 m thick formed directly on the underlying bedrock. Commonly the soil has a skeletal profile, and is less than 1 m thick.

UOS00 *Sand (unknown origin)*

Some sand deposits, particularly in inland locations, cannot be attributed to any particular origin. Such deposits should be placed in this category.

UOC00 *Clay (unknown origin)*

Some clay deposits cannot be attributed to any particular origin. Such deposits should be placed in this category.

SDT00 *Sediments (terrestrial)*

Materials deposited on the land surface by terrestrial geomorphic processes.

SDA00 *Alluvial sediments*

Materials deposited on the land surface from transport by flowing water confined to a channel or valley floor.

SDA01 *Channel deposits*

Alluvium which is deposited in an alluvial channel. It is commonly coarser than surrounding deposits, and is found in both active and relict channels. It includes deposits in cut–off meanders, and point bar deposits.

SDA02 *Overbank deposits*

Alluvium which is deposited outside an alluvial channel from flowing water which has overflowed from the channel. It includes levees and back swamp deposits.

SDC00 *Colluvial sediments*

Sediment mass deposited from transport down a slope by gravity. Compared with alluvium, colluvium lacks bedding structure, is more variable in grain size, and contains material derived locally.

SDC01 *Scree*

Scree, sometimes called talus, is colluvium deposited after falling or rolling from cliffed or precipitous slopes, consisting of loose rock fragments of gravel size or larger.

SDC02 *Landslide deposit*

Colluvium rapidly displaced down slope by failure of a mass of earth or rock. If the mass was not already part of the regolith the landslide incorporates it into the regolith. Original rock structures are fragmented and tilted by the action of the landslide.

SDC03 *Mudflow deposit*

Colluvium rapidly displaced down slope mixed with water to form a dense fluid. The material is more thoroughly disaggregated than that of a landslide deposit, but lacks the bedding and sorting of grain sizes seen in alluvium.

SDC04 *Creep deposit*

Normally a thin layer of rocky or earthy colluvium which moves very slowly down slope. In some circumstances it may be recognised by, for example, bending of rock bands down slope, but in other cases can only be inferred.

SDC05 *Sheet flow deposit*

Colluvium deposited from transport by a very shallow flow of water as a sheet, or network of rills on the land surface. Sheet flow deposits are very thin except at the foot of a slope and beneath sheet flood fans.

SDC06 *Fanglomerate*

Colluvium deposited on a colluvial fan. It typically has a bimodal grain size distribution. Bedding is lenticular across the fan, and long, usually lobate in a down-fan direction.

SDE00 *Aeolian sediment*

Sediment deposited from transport by wind.

SDE01 *Aeolian sand*

Wind blown sediment of sand size, often taking the form of dunes, with characteristic bedding structures.

SDE02 *Loess*

Aeolian sediment of silt size, often deposited over the landscape as a blanket.

SDE03 *Parna*

Aeolian sediment of clay size, commonly transported as flakes of larger size, up to sand size.

SDS00 *Coastal sediments*

Sediments deposited in the coastal zone by coastal processes.

SDS01 *Beach sediments*

Sediment mass deposited from transport by waves or tides at the shore of a sea or lake.

SDS02 *Estuarine sediments*

Sediments deposited in an estuary or lagoon, from transport by tidal currents.

SDL00 *Lacustrine sediments*

Sediments deposited from transport by waves and from solution and suspension in still water in a closed depression on land.

SDM00 *Marine sediments*

Sediments deposited from transport by waves and from solution and suspension in sea water. Marine sediments may occur in the regolith where the sea has withdrawn from an area during the Quaternary Period.

SDG00 *Glacial sediments*

Sediment deposited from transport by moving ice. It is neither bedded nor sorted. It has a matrix of clay or silt enclosing larger particles of unweathered rock ranging up to large boulders.

SDF00 *Fill*

Artificial sediment mass formed by earth moving works. Fill is sometimes compacted to the status of a very weak rock, but typically remains an earth mass.

VOL00 *Volcanic material*

Material derived from igneous activity at the surface.

VOL01 *Lava*

Igneous rocks solidified after eruption on to the land surface.

VOL02 *Volcanic ash (tephra)*

Material deposited on the land surface after ejection from a volcano. It often contains a proportion of highly weatherable glass, and mantles the landscape.

EVA00 *Evaporite*

Sediment formed by the precipitation of solutes from water bodies on the land surface, typically as lacustrine sediments.

EVA01 *Halite*

Evaporite consisting of sodium chloride.

EVA02 *Gypsum*

Evaporite consisting of hydrated calcium sulphate.

IND00 *Indurated material*

Regolith material that has been hardened and/or cemented to some degree. This category can be further subdivided according to the dominant indurating material, as follows:

IND10	Bauxitic induration
IND20	Calcareous induration
IND30	Clay induration
IND40	Ferruginous induration
IND50	Gypsiferous induration
IND60	Siliceous induration
IND70	Humic induration

IDU00 *Duricrust*

Mass of hard material formed within the regolith by either relative or absolute accumulations of natural cements in sediment (which may be variably weathered), saprolite or partially weathered rock.

IDS00 *Completely cemented duricrust*

Smooth textured duricrust where 90% of the material has been cemented. The suffix "crete" is used for these materials.

IDS10 *Alcrete (bauxite)*

Completely cemented duricrust cemented mainly by aluminium compounds.

IDS20 *Calcrete*

Completely cemented duricrust cemented mainly by calcium carbonate.

IDS40 *Ferricrete*

Completely cemented duricrust cemented mainly by iron.

IDS41 *Massive ferricrete*

Ferricrete which has little or no internal differentiation.

IDS42 *Nodular ferricrete*

Ferricrete which is differentiated internally and gives the appearance of cemented nodules.

IDS50 *Gypcrete*

Completely cemented duricrust cemented mainly by gypsum.

IDS60 *Silcrete*

Completely cemented duricrust cemented mainly by silica.

IDM00 *Moderately cemented duricrust*

Duricrust where the material is 70 – 90% cemented. It often has a grainy texture and may be mottled. These materials can be further subdivided as follows:

IDM20	Calcareous
IDM40	Ferruginous
IDM60	Siliceous

IDP00 *Partially cemented duricrust*

Duricrust with less than 70% cemented material, often with an open texture, for which the term hardpan is used. This category can be further subdivided:

IDP30	Clay hardpan
IDP60	Siliceous hardpan
IDP70	Humic hardpan

INO00 *Nodules*

Nodules are irregular to spherical units of regolith material that occur enclosed within the regolith, as lag, or in duricrusts. They generally have rounded edges. They are distinct because of a greater concentration of some constituent, a difference in internal fabric or a distinct boundary with the surrounding material. We use the term as more or less equivalent to the *glaebule* of Brewer (1964). It does not include fragments of weathered rock, or coarse sedimentary particles unless they have been modified. For example, a fragment of rock weathered and coated with a cutan would fit our definition.

There are many possible subdivisions of this category, such as pisoliths and concretions. These may be included in revisions. The following subdivisions of this category are included at this time:

INO10	bauxitic nodules
INO20	calcareous nodules
INO30	clay nodules
INO40	ferruginous nodules
INO60	siliceous nodules

4.7.2 Degree of Weathering

For each regolith type listed above it is necessary to assess the degree of weathering. Speight and Isbell (1990) have developed a schema for *in situ* rocks. We have modified this slightly, and have included practical tests from Ollier (1965). We have extended Speight and Isbell's schema to cover transported materials.

0 *Unknown*

This category is used during reconnaissance mapping when an RTU has been recognised on imagery or maps, but has not been visited in the field.

1 *Unweathered*

Regolith with no visible signs of weathering. Normally this class will be confined to sedimentary regolith types because, by definition, fresh bedrock is not regolith.

2 *Slightly weathered*

Slightly weathered rock has traces of alteration, including weak iron staining, and some earth material.

Corestones, if present, are interlocked, there is slight decay of feldspars, and a few microfractures. Slightly weathered rock is easily broken with a hammer.

Slightly weathered sediments have traces of alteration on the surfaces of sedimentary particles, including weak iron staining. Some earth material may be present, filling voids between coarse particles.

3 *Moderately weathered*

Moderately weathered rock has strong iron staining, and up to 50 % earth material. Corestones, if present, are rectangular and interlocked. Most feldspars have decayed, and there are microfractures throughout. Moderately weathered rock can be broken by a kick (with boots on), but not by hand.

Moderately weathered sediments have strong iron staining, and up to 50 % earth material. Labile particles up to gravel size are completely weathered. Larger particles have thick weathering skins. Most feldspars in larger particles have decayed.

4 *Highly weathered*

Highly weathered rock has strong iron staining, and more than 50% earth material. Core stones, if present, are free and rounded. Nearly all feldspars are decayed, and there are numerous microfractures. The material can be broken apart in the hands with difficulty.

Highly weathered sediment has strong iron staining, and more than 50% earth material. All except the largest particles are weathered right through. Boulders have thick weathering skins.

5 *Very highly weathered*

Very highly weathered rock is produced by the thorough decomposition of rock masses due to exposure to land surface processes. The material retains structures from the original rock. It may be pallid in colour, and is composed completely of earth material. Corestones, if present, are rare and rounded. All feldspars have decayed. It can easily be broken by hand.

Very highly weathered sediment is thoroughly decomposed, but still retains the shapes of the original sediment particles, as well as laminations and bedding. It is composed completely of earth material.

6 *Completely weathered*

Completely weathered rock retains no structures from the original rock. There are no corestones, but there may be mottling. It is composed completely of earth material.

Completely weathered sediment retains no structures from the original sediment. It is composed completely of earth material. There may be mottling.

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REGOLITH TYPE DESCRIPTION

The fields on the following pages relate to one (1) regolith type. There may be many regolith types within one Landform Unit.

MAP UNIT # ________ **LANDFORM** ______________________________

REGOLITH TYPE: ________________________________ MAJOR/SUB: _____

See the Regolith Type Table for list of valid Regolith Types.

DEGREE OF WEATHERING: ___ INDURATION: ______________________________

Degree of weathering and induration fields are modifiers for the regolith type. In cases where indurated material has been chosen as the regolith type, a degree of weathering code would not normally be entered. The entry would be 0 for unknown.

The choices for the Induration field are selected from the Regolith Types table. The Induration field is used if the original primary material, is known, in which case it acts as modifier to the primary material which would appear in the regolith type field. In many cases, however, the primary material is obscured by the induration making its identification impossible. In that case the type of <u>induration</u> would be selected as the regolith type and entered into the regolith type field. The induration field would be left empty.

MAXIMUM OBSERVED THICKNESS OF THE REGOLITH TYPE: _______

REGOLITH PROFILE

The regolith profile field describes the profile characteristics of the regolith, including any truncation or covering that may have occurred.

REGOLITH DISTRIBUTION

The regolith distribution field describes the three dimensional landscape position of the regolith type.

AGE: From: ______________________________ to ______________________________

COMMENTS ON AGE: ____

The Age fields are entered if the regolith type has been dated or an age inferred from work done. The ages can be entered as a range, eg From age 1 to age 2, or as a single age entered into the first field if there is no age range. Ages are entered as full names, eg Pliocene or Cretaceous, and may include prefixes, eg Upper, Middle etc. The Comments on Age field is for details on how the date was obtained, eg dating technique or inferred date, accuracy etc.

LANDFORM UNIT

There may be many Landform Units within one Regolith Terrain Unit.

MAP UNIT # ________

LANDFORM: ______________________________________ MAJOR/SUB: _____

See the Landform Table for list of valid Landforms.

RELIEF OF LANDFORM UNIT:

STRUCTURAL CONTROL: _____ Enter NS if no structural control is evident.

ENVIRONMENTAL HAZARDS: Enter a code or make a brief comment (Enter NA if no Enviromental Hazard evident).

MAXIMUM OBSERVED THICKNESS OF REGOLITH WITHIN THE LANDFORM

The thickness code is entered into this field: ________

SOIL

Use this field if the soil information can be related to the Landform.

GENERAL LANDFORM UNIT COMMENTS

The following fields have many to one relationships to the Landform.

BEDROCK LITHOLOGY AND STRATIGRAPHY

Enter the bedrock lithology (The Lithology table contains the list of valid choices) and stratigraphic details. The 60 character Lithology Details field is available for recording extra information about the bedrock.

LITHOLOGY	LITHOLOGY DETAILS	STRATIGRAPHY AND AGE

DRAINAGE

Enter the drainage pattern, the major/subordinate (M/S) code, the drainage character, the drainage type and the drainage spacing.See the Drainage Table for list of valid Drainage Patterns.

PATTERN	MAJOR/SUB	CHARACTER	TYPE	SPACING

GEOMORPHIC PROCESSES

Enter the geomorphic process, the major or subordinate process (M/S) code, and the active or relict (A/R) code. See the Geomorphic Processes Table for list of valid Geomorphic Processes.

GEOMORPHIC PROCESS	MAJOR/SUB	ACTIVE/RELICT

WEATHERING PROCESSES

Enter the weathering process, the major or subordinate process (M/S) code, and the active/relict (A/R) code. See the Weathering Processes Table for list of valid Weathering Processes.

WEATHERING PROCESSES	MAJOR/SUB	ACTIVE/RELICT

RTMAP DATABASE - MAPPING UNIT DESCRIPTIONS

MAP UNIT # ___________ UNIT ID ___________

The fields on page 1 and page 2 relate to the whole Regolith Terrain Unit. These fields are filled once only for each unit. Full details on recording data, field lengths, attribute types and definitions can be obtained from BMR Record 1991/29, RTMAP, BMR Regolith Database Field Handbook.

ELEVATION: From _______ m to _______ m

REGOLITH

TERRAIN

VEGETATION

GENERAL UNIT COMMENTS

SOILS

If the information on soils is detailed enough, relate the soil type to the landform unit by using the soil field on the landform unit description page, (page 3). If the information is only at a general unit level then use this field.

The following fields have many to one relationships to the Regolith Terrain Unit.

TECTONIC ELEMENTS

Enter the Tectonic element/province details in the following fields.

REGOLITH PROVINCE

Enter the Regolith Province details followed by the major/subordinate (M/S) code.

REFERENCES

Record reference details (Authors, date, title and source), and maps referenced (Title, scale, date, and source).

COMPILER DETAILS

Enter the compilers name, affiliation and date of compilation